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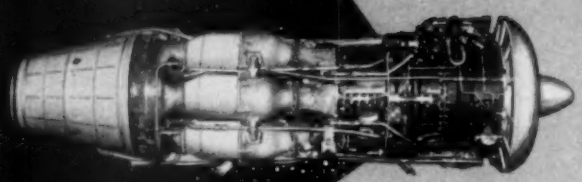

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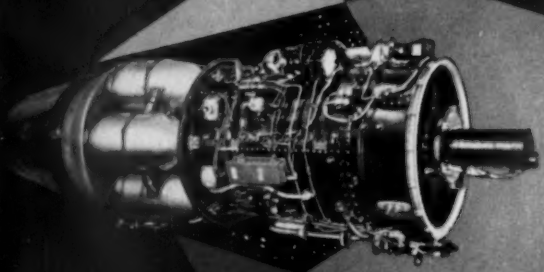

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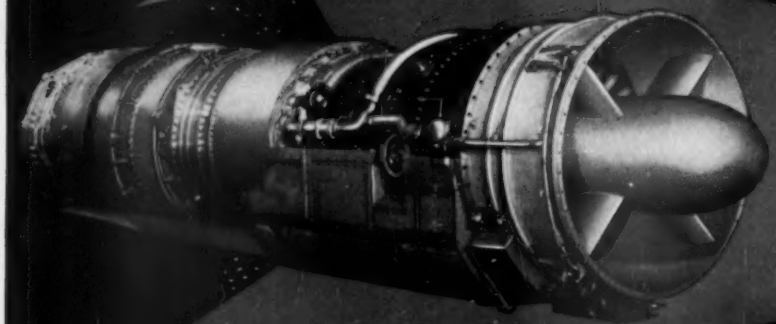

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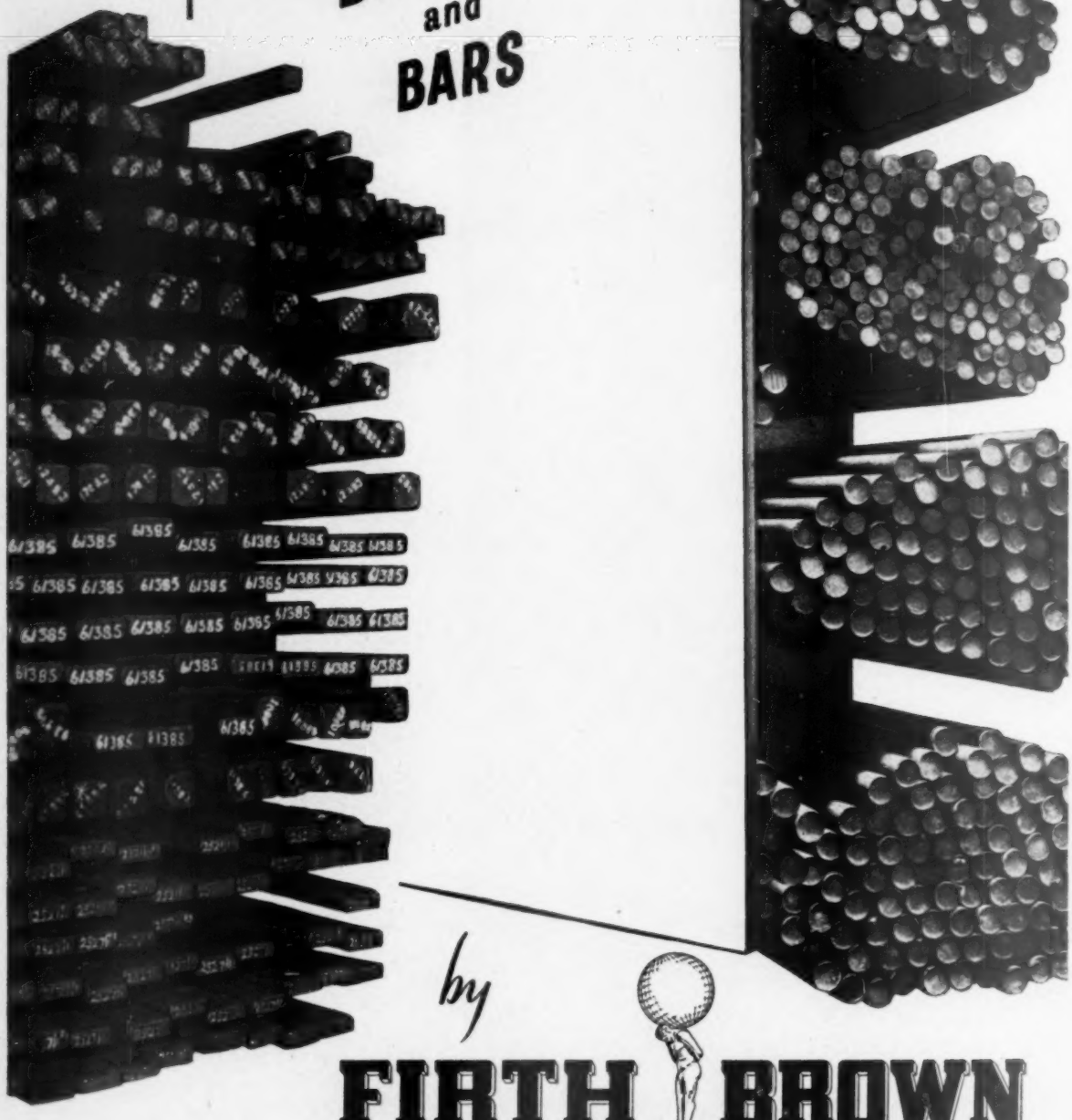

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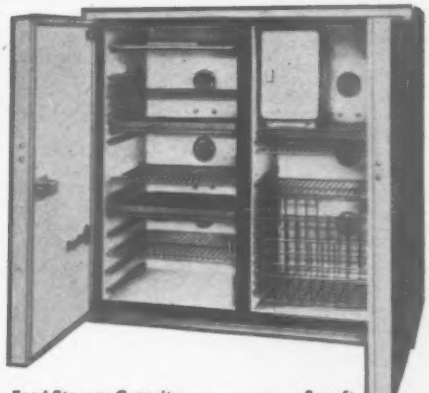

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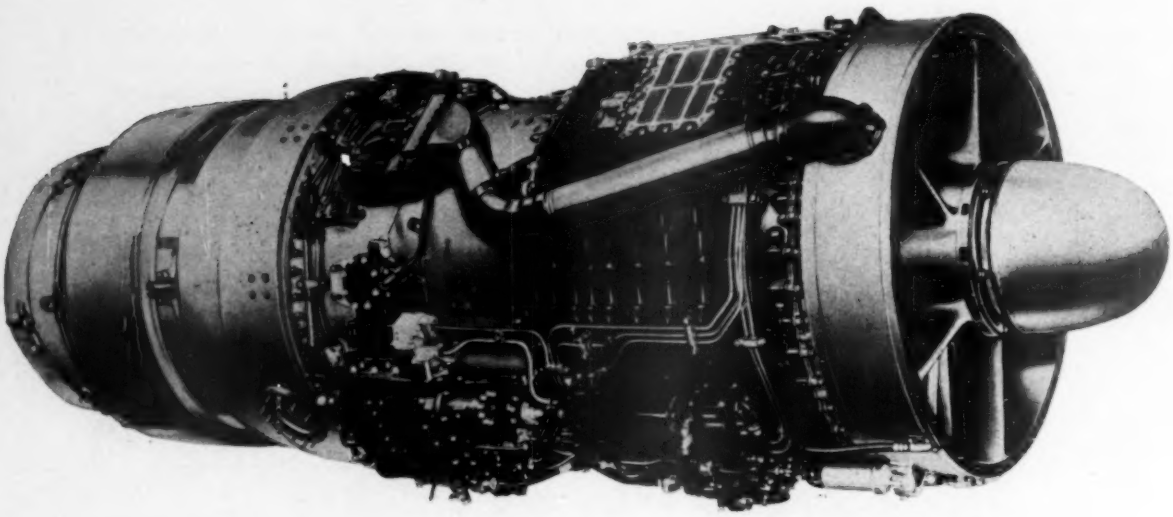

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THE AEROPLANE

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ON MATTERS OF PROPULSION

THROUGHOUT the World, wherever there is an aircraft industry, a large and important part in it is played by those who design, develop and manufacture the means of propulsion whereby the inventiveness of the airframe specialists can be brought to proper fruition. Indeed, without these propulsive efforts much of the aeronautical progress that has been seen during the past few years could not have been realized. Advances in powerplant technology have already made it possible for man-made objects to be placed into orbit round the Earth and Sun. Although we in this country cannot as yet claim to have participated directly in this particular effort, we can at least take a modest pride in having led the powerplant world in the development of turbojet and turboprop engines. And the scope of our aero-engine industry continues to grow.

A very good idea of its present status is in fact given by the S.B.A.C.'s eloquent statistics for the aeronautical export market. As we recorded in our pages only last week, no less than £49,557,723-worth of British aero-engines was sold abroad during 1958. This figure, remarkable enough in its own right in being a little over one-third of the entire aero-exports for the year, was the more noteworthy for the fact that it represented an increase of 22% over the previous year's engine export value—which itself had stood at a record level. To these figures must be added the very sizeable "hidden exports" represented by the income from licence agreements; for many of our engines are built abroad.

These noteworthy achievements come from an industry that comprises some half-dozen long-established companies each with an individuality of its own. During the past 12 months, however, there have been moves towards a merger between two of the larger units and it would seem appropriate that in this particular issue of THE AEROPLANE we record details of the final marriage between Bristol Aero-Engines and Armstrong Siddeley Motors to form one large and comprehensive organization. This is a significant step in the fortunes of both these companies, for together they will now be one of the largest powerplant concerns in the World.

In all progressive industries—and the aero-engine business is no exception—there is never a time when there are no problems urgently requiring solution. For example, although the turbojet is now a well-established prime-mover, the greater emphasis on its use in civil aircraft puts constant pressure on the powerplant designer for lighter units and lower fuel consumptions. These are the obvious results of becoming involved in highly competitive commercial operations. But another, even more pressing, problem has come into being of late. Aeroplanes operating from large civil airports on the fringes of the World's cities, take-off and land and fly at low altitude over populous areas. And, because the development of the high thrust needed for successful commercial operation has inevitably brought with it a corresponding increase in noise output, they are great disturbers of the peace.

This production of noise and the need to reduce it to a minimum has, in fact, become one of the most important problems facing the aeronautical powerplant engineer at the present time. Indeed, we record in this issue a recent lecture before the Royal Aeronautical Society at which there was lively discussion on this very matter. From it there emerged a general acceptance that the proper answer must lie in designing the powerplant from the outset with the noise problem very much in mind. Here the by-pass or ducted-fan type of engine looks likely to provide the best solution.

It might, perhaps, be noted here that a ducted fan of another sort has recently been in the news in the United States as the means of elevating a "flying jeep." Although this can hardly be categorized as a powerplant as such, it is of some significance as a special approach towards providing the vertical thrust for a VTOL aircraft and as a good example of close integration of airframe and powerplant design. This itself is rapidly becoming a special facet of powerplant technology and there are many promising VTOL turbojet developments either for use as direct-lift engines or using some form of deflected jet efflux.

Another new powerplant field of a similarly specialized nature is that represented by the small tip jet units — ramjets and pressure-jets — that have been developed especially for driving helicopter rotors. Larger ramjets and rocket engines are, at present, somewhat restricted in application—being used, in the main, for missiles. But studies are being made of the more refined forms of turbo-rocket and turbo-ramjet powerplants for civil supersonic aircraft—and these may well develop into an important new form of prime-mover.

In this issue of THE AEROPLANE a major part of the space available has been devoted to matters concerning powerplant affairs. Among these pages are authoritative contributions which sum up the current trends in two main branches of the art. In both it will be found that there are still plenty of problems to exercise the ingenuity of the powerplant specialist. It is this, perhaps, which makes this particular branch of the aeronautical sciences one of the most stimulating at the present time.

Matters of Moment

Bristol Siddeley Developments

LAST WEEK, details were made available of the final pattern of the arrangements whereby Armstrong Siddeley Motors and Bristol Aero-Engines have been formed into Bristol Siddeley Engines, Ltd. The whole share capital of this new company has now been acquired by the two parent bodies, Hawker Siddeley Group and the Bristol Aeroplane Company, in equal proportions. Bristol Siddeley Engines for its part takes over the entire share capital of its two components Armstrong Siddeley and Bristol Aero-Engines and will also control the whole of their operations as well as those of Bristol Cars, Ltd.

A preliminary hint of this latest move towards rationalization within Britain's aero-engine industry was made by the Minister of Supply early last month when he revealed details of plans for the building of the TSR-2 "Canberra replacement"—the engines for which are to be developed by Bristol Siddeley. He stated then that the two companies concerned had indicated that they were "now proceeding to complete financial integration." These plans have now, it appears, come to full fruition.

Readers will recall that Bristol Siddeley Engines was formed last year as a governing company to control the collaborative efforts of Bristol Aero-Engines and Armstrong Siddeley Motors. This initial move has now been taken a stage further and the complete merger of the two companies has been brought about. As a result, the new aero-engine concern will be one of the largest of its kind in the World and will have comprehensive design, manufacturing, research and development facilities for a complete range of powerplants from ramjets, through turbo-props and turbojets of all sizes, to rocket engines.

The "caretaker" board brought into being for the founding of Bristol Siddeley Engines last year, has now been reconstituted with Sir Reginald Verdon Smith as chairman and Sir Roy Dobson as vice-chairman. Mr. H. T. Chapman will be the deputy chairman resident in Coventry; and Sir Alec Coryton, the deputy chairman resident in Bristol. Managing director of the new company is Sir Arnold Hall. Other members of the board include: Air Cdre. F. R. Banks, sales director; Mr. B. Davidson, commercial director; Mr. W. F. Saxton, production director; Mr. G. L. Hack, assistant production director; Dr. S. G. Hooker, technical director (aero); Mr. W. H. Lindsey, technical director (non-aero); and Mr. W. Masterton.

Dr. E. Warlow Davies, at present deputy chief engineer of Bristol Aero-Engines, will be the chief engineer (aero) of the new company and will also be a special director. Other special directors of the new company are Mr. J. E. Attwood, Mr. J. Innes, and Mr. R. Ninnes; they are directors of the two component organizations and do not become members of the new board but will continue in their present executive positions.

COMMEMORATED. — It is fitting that in this "Powerplants" issue of THE AEROPLANE, we record the presentation of the first Halford Memorial Lecture in commemoration of the invaluable contribution to powerplant development made by Major Frank B. Halford, chairman and technical director of the de Havilland Engine Co., who died in 1955. The lecture was given on February 5 by Mr. J. L. P. Brodie, the company's engineering director.

The present secretary of Bristol Siddeley Engines, Sir Mark Norman, Bt., will be executive assistant to Sir Arnold Hall; and Mr. F. T. Blakey, at present secretary of Armstrong Siddeley Motors, will become secretary of the new company. Chief accountant of the new company will be Mr. F. M. Burns, at present financial director of Bristol Aero-Engines.

The Southall Accident

AN abnormal situation requires unusual procedures and it was, no doubt, inevitable that the 11-day, much-adjourned inquest on the victims of the accident to the Independent Air Travel Viking, at Southall on September 2 last year, should have involved the taking of so much technical and near-technical evidence in a non-specialist environment. The proceedings have, as a result, been somewhat confusing for those onlookers who have been interested in causes rather than in legal questions of blame, if any. The entire affair has also been most unfortunate for the air transport business because emphasis had to be placed on certain aspects of a particular operation.

Nevertheless, since the inquest was widely reported, it is necessary for us to summarize some of the points raised in advance of the findings of a public inquiry—which will, no doubt, marshal and question the evidence in a manner which is not so easily possible at an inquest. The most important technical aspect of the case was the way in which the recordings of RT conversations could be used to follow and understand the events during the entire period of the emergency which culminated in the accident.

The Viking, G-AIJE, had been flown in to Blackbushe from Bordeaux on September 1, when a defective constant-speed unit,

FOR ARGENTINA.—On January 27 the first Comet 4 for Aerolineas Argentinas (LV-PLM) made its initial flight of 3 hr. 24 min. It is seen here taking off from Hatfield. Aerolineas expect to start operations with their first three Comets this spring.

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TURBOPROP PLAN.—Encouraging progress is being made with the Vickers Vanguard, which made eight flights totalling 10 hr. 45 min. in nine days after its first flight on January 20. The low noise level, at take-off and in the circuit, and the quietness of the flight deck have already attracted attention.

causing an oil leak, was reported. A reconstructed unit was fitted, but, on a positioning flight to L.A.P., the oil leak persisted and more work was done on the unit before and while the aircraft was being loaded (with Proteus powerplants for El Al) during the early hours of September 2.

While at 7,000 ft. on course to Seaford via the Dunsfold range the captain reported engine trouble, said that he wished to return to Blackbushe and was cleared back to Dunsfold at the same altitude. This was at 06.09 hrs. and height was then being maintained. The defective starboard engine was then being allowed to windmill (suggesting that the trouble might, for instance, have been low oil pressure rather than mechanical failure), but was later feathered. The aircraft was cleared by ATC down to 5,000 ft. and then, at 06.15 hrs., to 3,000 ft. The ground was obscured by mist and/or low cloud and presumably remained so throughout the flight.

At 06.20 hrs. Airways Control reported a radar echo, which might, it was thought, be the Viking approaching Epsom, and a B.O.A.C. pilot in the area said that he could see a Viking slightly above him. The Viking captain was asked to confirm that he was en route to Blackbushe with his ADF correctly tuned in to that airport's NDB (Mike Bravo). This was confirmed by the captain who then asked for GCA assistance and said he could not "at the moment" unfeather his starboard propeller. At 06.26 hrs. he told Blackbushe that he was 10 miles to the east of the airport and having difficulty in maintaining height, which was then 800 ft. A minute later he reported that the Viking was down to 500 ft. and asked for immediate GCA. At about 06.29 hrs. he reported his height as 200 ft.

London's ATC considered that the Viking—by then down to a height of 100 ft. and presumably not in sight of ground—might be approaching L.A.P. and requested an immediate climb-away. Airways Control believed it to be south-west of the airport; the crash crew stood by and all outbound traffic was stopped. This was at 06.31 hrs. The final "May Day" call was at 06.32 hrs. and the aircraft was then about four miles north-east of L.A.P. and about 25 miles north-east of Blackbushe.

Furthering Agricultural Aviation

ONE of the rapidly expanding specialist sections among operators of aircraft these days is that which comprises those concerned in one way or another with agricultural aviation. So far, in this country, however, this thriving band has tended to be somewhat widely distributed and there are many who have felt that better appreciation of the use of aircraft for agricultural purposes would be obtained if there were a closer relationship between all the interested parties.

In point of fact, Mr. S. W. G. Foster, A.F.R.Ae.S., a design consultant of Hampton, Middlesex, has been working energetically towards this end and last week he arranged a meeting of people directly interested in agricultural aviation. All facets of this important new branch of aeronautical effort were represented.

Mr. Foster informed the meeting of his attempts to form a group to further the use of the aeroplane and the helicopter in the field of agriculture and to provide facilities for the research chemist, entymologist, chemical engineer, operator, pilot, farmer, aircraft technician, and manufacturer, to meet and interchange ideas and information on this specialized subject. It was agreed that such facilities would benefit the development of the aircraft in this sphere.

Among the people present were representatives of the Royal Aeronautical Society and after due discussion it was hoped that recognition of the proposed group would eventually be obtained from the R.Ae.S. so that full co-operation would be enjoyed by all sides.

The meeting also agreed on a provisional committee to meet on February 6 to discuss the matter further and to implement the formation of the group. The committee would also arrange the next meeting based broadly on suggestions made at this initial one. Mr. Foster mentioned that he had access to several films concerning agricultural aviation which, he felt, would be of great general interest to those present. These could possibly form the basis of a later meeting which it was hoped could be arranged for the end of February.

Further support for the group would be welcomed. Readers who are interested should write to Mr. S. W. G. Foster at 37 Broad Lane, Hampton, Middlesex.

Questions on the TSR-2

ANSWERS to recent Parliamentary questions give new information about the TSR-2 tactical support and reconnaissance aircraft, which is being developed jointly by Vickers-Armstrongs and English Electric. Our issue of January 9 gave the first official news of this Canberra replacement.

Compared with the Blackburn NA39 low-level naval strike aircraft the TSR-2 will be more advanced and have a slightly different rôle. Its take-off and landing run will be much shorter and it will have better facilities for blind navigation over land. It will enter service by about 1964 or 1965, and remain operational until the 1970s. Doubts were expressed that it could be developed from specification to operational service in five years, but the Secretary of State for Air, Mr. George Ward, said that he had every confidence in the assurances given by the industry.

Questioned about the range of the TSR-2, Mr. Ward said that it was substantially greater than that of the Mace flying bomb. The Mace is reported to have a range of more than 650 miles.

PROGRESS AT BITTESWELL.—Up to January 27 the Armstrong Whitworth A.W.650 Argosy (four Rolls-Royce Dart turboprops) had flown more than 10 hr. on test. It first flew on January 8.

General Aviation News

SARO-NUCLEAR ENTERPRISES.—Following the close contact recently maintained by Saunders-Roe, Ltd., with Nuclear Enterprises (G.B.), Ltd., of Edinburgh, a new jointly owned company has been formed. This company, Saro-Nuclear Enterprises, Ltd., has its head office at 53 Parliament Street, London, S.W.1; its activities will cover the fields of applied irradiation and the application of isotopes to industrial processes.

JET ASSISTANCE.—An Aerojet-General Junior Jato unit being installed in one of the engine nacelles of a Beechcraft Super 18 for stand-by use. This aircraft is the first civil type of less than 10,000 lb. loaded weight so fitted.

NO SPACE DECISION.—The Minister of Supply said, on January 23, that no decision had yet been taken to embark on a British programme of space research with satellites.

MORE ABOUT PARIS.—June 14, the third day of the 23rd French International Air Show (June 12-21), will be set aside for commercial aviation; June 18 for rotary-wing aircraft, and June 20 for individual flight demonstrations. The last day of the show will include Service participation. Days are also to be devoted to aviation and space medicine, and sporting and touring aircraft.

BRANTLY HELICOPTER.—For sales, distribution and later manufacture of the Brantly B-2 two-seat helicopter a British company has been formed. It is Brantly Helicopters, Ltd., of 131 Ystrad Road, Fforestfach, Swansea. The Brantly B-2 has a 180-h.p. Lycoming engine and costs $19,950 in the U.S.

LIFE-SAVER.—The Lockheed Aircraft Corpn. has developed a new device intended to retrieve parachutists who may become entangled with trailing lines when jumping from a C-130A Hercules. The "jumpmaster" directing the operation can if necessary hook up a retriever cable and reel the man back via an electrically driven winch. A section at the rear of the undercarriage fairing immediately ahead of the exit door opens slightly outwards to form a windshield. The retriever system can also be applied to the Fairchild C-123.

TURBOPROP FLIGHT.—A Cessna L-19 Bird Dog powered by a Boeing 502 series turboprop recently made a 2,950-mile flight from Boeing Field, Seattle, to Fort Rucker, Alabama, piloted by Maj. J. Cranford, U.S. Army Aviation Board. A height of 27,000 ft. was reached, and the flight took 26 hr. flying time. The Cessna was refuelled on the ground from an Otter which accompanied it.

PROPELLER OVERHAUL.—A.R.B. approval for de Havilland propellers on the Bristol Britannias of B.O.A.C. is now for an overhaul period of 2,100 hr. In the two years since introduction of Britannia passenger services the propellers have flown a total of 400,000 hr.

COAST-TO-COAST.—On January 24 two Douglas A4D Skyhawks of the 2nd Marine Air Wing, Cherry Point, N. Carolina, non-stop and without refuelling, made a 2,082-mile coast-to-coast flight in 4 hr. 25 min.

TRANS-AMERICA.—Piloting an F-105 Thunderchief, Capt. W. White, U.S.A.F., flew the 3,850 miles from Eielson A.F.B., Alaska, to Eglin A.F.B., Florida, in 5 hr. 27 min., an average speed of 700 m.p.h. The Thunderchief was twice refuelled in flight.

STRENGTHENED HERCULES.—The first of 50 Lockheed C-130A Hercules strengthened to carry a payload of about 20 tons at 35,000 ft. has been delivered to the U.S.A.F. at Sewart A.F.B., Tenn. Improvements include re-skinning of 30% of the fuselage.

ENDURANCE TEST.—R. Timm and W. Cook spent their 54th day in the air over California on January 27 flying a single-engined Cessna. They passed the "World record" mark on January 23 when they had been airborne for 50 days 16 min. The aircraft is refuelled twice daily at zero level from a speeding tanker on a specially cleared road.

ON THE THRESHOLD OF SPACE.—The North American X-15 manned space-research vehicle was scheduled to be carried to height under the wing of its parent B-52 for the first time on February 1. Free flights are to be made later.

News About People

F.E.A.F. TOUR.—The Director of the W.R.A.F., Air Commandant Dame Henrietta Barnett, D.B.E., A.D.C., was due to leave on February 2 for a tour of the Far East Air Force. She will visit W.R.A.F. units at R.A.F. Changi, Seletar and Fraser Hill, Singapore, and also R.A.A.F. Butterworth, Malaya, before returning on February 18.

R.Ae.C. Awards

MR. JOHN CUNNINGHAM, chief test pilot of the de Havilland Aircraft Co., Ltd., and Mr. Peter Bugge, have been awarded the Britannia Challenge Trophy for 1958 in recognition of their flights and development work with the Comet 4.

Lord Brabazon, the club's president, receives a Gold Medal for his services to aviation; a Silver Medal goes to Mrs. Ann Welch for her contribution to the gliding movement and as manager of the British teams in World championships; and Sgt. A. W. Gough receives a Bronze Medal for instructional work and for his 347-mile British distance record.

For setting up the London-Valletta point-to-point record last June, Lieut-Cdr. D. F. Robbins, R.N., receives the Geoffrey de Havilland Trophy. He flew a Supermarine Scimitar at an average speed of 588.04 m.p.h.

CAMBRIAN CHANGES.—Mr. John Morgan has assumed chairmanship of Cambrian Airways during the extended absence overseas of Mr. J. H. Watts. The joint managing directorship has been terminated and Wg. Cdr. L. B. Elwin, A.F.C., continues as sole managing director. Mr. W. W. Stanley, A.C.A., company secretary, is appointed to the Board. Mr. B. J. T. Callan, formerly commercial manager, is now operational manager, and Mr. S. F. Richardson, from the Southampton office, is appointed sales representative.

ALVIS APPOINTMENTS. — Maj. R. E. Nicoll, A.R.Ae.S., until recently commercial director of Westminster Airways Servicing, Ltd., and for many years sales manager of Handley Page, Ltd., has

Maj. R. E. Nicoll (left) and Mr. T. F. Lenton.

joined Alvis, Ltd., as sales manager, succeeding Mr. T. C. Wallace. Mr. T. F. Lenton, who has been with Alvis since 1938, takes over as service manager from Wg. Cdr. F. White, who is emigrating to Australia.

THE LATE MR. MASSEY HILTON.—A large congregation attended the memorial service to Mr. Louis Massey Hilton at St. Clement Danes on January 30. In his address, Vice-Admiral Couchman paid tribute to three characteristics of Mr. Hilton — his courage, his steadfastness and his charity. The Air Council was represented.

A D.H. Fund

THE John de Havilland Award, which was established in memory of the third son of Sir Geoffrey and Lady de Havilland who was killed in 1943, is to take a new form. It will continue to be administered by the S.B.A.C., but its purpose will now be to develop the power of leadership, in those with the potential or rising to very responsible positions in the aircraft industry by the opportunity of experience; the emphasis lies in the spirit of adventure, initiative and resource.

Candidates, aged 18 to 25, are invited to make their own proposals for the use of the award. These can be wide in scope.

One award, valued at £400, will be made per year; its use must not start before August or September next.

Applications should be sent, not later than May 15, to the S.B.A.C., 29 King Street, London, S.W.1, from whom further information may be obtained.

BELL ENGINEER.—Mr. Jan Meijer Drees, chief designer of the Dutch N.H.I. Kolibrie ramjet helicopter, has joined the Bell Helicopter Corpn. as senior research engineer.

S. A. HIRST.—We regret to record that Mr. Stuart A. Hirst, chairman of the Blackburn Aeroplane and Motor Co., Ltd., from 1914 until the end of the First World War, died on January 24 at the age of 81. He was a founder of the Yorkshire Aeroplane Club, which originally came into being in 1909, and a member of the Society of Aircraft Constructors.

NEW APPOINTMENTS.—Following the formation of English Electric Aviation, Ltd., these new appointments have been made. Left to right, W. Shorrock (general manager, Preston); W. Harpley (deputy general manager, works, Preston); T. O. Williams (aircraft manager, Preston); R. F. Creasey (director of engineering, aircraft division); F. D. Crowe (chief engineer, aircraft division); A. E. Ellison (chief designer, aircraft division); L. H. Bedford (director of engineering, guided weapons division), and G. R. Jefferson (chief engineer, guided missiles division).

Commercial Aviation Affairs

DEMONSTRATING DECCA.—The Ministry of Supply Comet 2E which is being used to demonstrate Decca/Dectra in North America (see last week's issue, pp. 120-121) left Boscombe Down for New York on January 30. Amongst those on board was Mr. E. C. Mekie, chairman of Silver City Airways, who, as a private venture, will take part in the demonstrations and discussions, explaining how Decca has helped the Silver City operations.

THIRD EAGLEMASTER. — Last week Eagle Aviation took delivery from North America of a third DC-6C Eaglemaster to be added to the two acquired by the company last autumn. This aircraft, registration G—APSA, is now being converted to Eagle's 100-seat standard at Blackbushe. The two earlier aircraft have now exceeded 2,200 hours' flying with Eagle on Government contract and charter work.

QANTAS NEW ROUTE.—Following completion of the new airport at Port Moresby, New Guinea, Qantas is to open a route from Sydney to Manila and Hong Kong via Port Moresby.

CONVAIR CONCEPT.—This is one of many supersonic airliner layouts studied by Convair. In the Convair view, the first supersonic transports are more likely to cruise at Mach 3 to 5, and be available in the 1970s, than to be Mach 2 aircraft available in 1965.

FOR AUSTRALIA.—The first Fokker F.27 Friendship (Rolls-Royce Dart turboprops) for Trans-Australia Airlines, seen here over snow-covered Dutch countryside.

MOSCOW SERVICE.—The Minister of Transport has made new proposals to Aeroflot for the inauguration of a Moscow-London service, jointly with B.E.A. Operation of the Tu-104 "for a trial period" would be accepted at London Airport subject to the use of one specified take-off runway, and the use of techniques calculated to restrict noise in nearby residential areas to the level of the Comet 4 or Boeing 707.

MOVE TO L.A.P. CENTRAL.—T.C.A. is to move from the north side to the central area of London Airport in April, and will be the first transatlantic operator to do so. The move is being made at the request of the M.T.C.A. to relieve pressure on the north side, and K.L.M. may also move across soon. A new long-distance terminal building is to be erected in the central area in due course.

CEYLON - CHINA RIGHTS.—Ceylon's Minister of Transport is to lead a delegation to China in March to negotiate traffic rights for Air Ceylon at Canton. The Ceylon Government is increasing its holding in Air Ceylon from 51% to 76% to overcome China's objection that rights for Air Ceylon at Canton would amount to granting rights also to K.L.M. (who hold the remainder of Air Ceylon's shares—see THE AEROPLANE, November 21, 1958, p.746).

NEW IN CANADA.—Sarnia Airlines, a new name among Canadian scheduled-service carriers, is now operating a four times daily service, with D.H. Doves, over the route Windsor (Ont.)—Sarnia (Ont.)—London (Ont.)—Toronto (Malton)—Toronto (Island Airport).

PACT APPROVED.—The C.A.B. has approved the mutual-aid plan whereby six major U.S. airlines agree to pay to any strike-bound member the above-average profits received by the other members during the period of the strike.

SKYWAY HOTEL.—A group of Canadian businessmen is financing construction of a 264-bedroom hotel—The Skyway—adjacent to London Airport. Work is to start at once on a 3½-acre site at the corner of the Bath Road and New Road, opposite the L.A.P. North international arrivals building.

AIR CHARTER LOSS.—Two members of the crew of six were killed when an Air Charter Super Trader (Tudor 4) crashed and burnt out while taking off from Brindisi on January 27. The aircraft was on a flight from Brindisi to London with general freight and is understood to have swung off the runway before becoming airborne, causing the undercarriage to collapse.

Military Aviation Affairs

FAIREY EXPORT.—The contract between Indonesia and the Fairey Aviation Co., Ltd., for the supply of 18 Gannets was signed on January 27. The aircraft, formerly operated by the Royal Navy, are to be fully reconditioned and fitted with new Armstrong Siddeley Double Mambas at Hayes and White Waltham. Sixteen of them will be AS.4s, the other two T.5s.

STRATEGIC FREIGHTER.—A statement by the Minister of Defence on the provision of a strategic freighter for R.A.F. Transport Command will be made shortly. This was stated in the House of Commons on January 28 by the Secretary of State for Air. It is understood that this statement can be expected within the next week—if it has not already been made before these words are read.

ARMY HELICOPTERS.—Bristol 192 helicopters will be delivered at the end of 1959 to meet Army requirements for a heavy helicopter. No decision has been taken about the Rotodyne, but it would come very much later. This was stated in the House of Commons by the Secretary of State for Air on January 28.

BUTTERWORTH SABRES.—A second R.A.A.F. squadron of Avon Sabres, No. 77, will leave Richmond, near Sidney, for Butterworth, Malaya, this month. The aircraft will fly via Darwin, the Philippines and North Borneo. An R.A.A.F. Canberra Squadron is also based at Butterworth.

COASTAL PHOTOGRAPHS.—The annual Coastal Command Photograph Competition and Exhibition is to be held at its Northwood Headquarters on February 9. Divided into 12 classes, it covers inter-squadron and inter-station competitions.

DOMINICA'S VAMPIRES.—Last week we reported that the Dominican Republic was trying to buy a number of surplus R.C.A.F. Vampires; the Canadian Trade Minister has since stated that no permit has been issued for their sale.

CRANWELL MUSEUM.—The R.A.F. College, Cranwell, is to have its own museum, and its Commandant, Air Cdre. D. F. Spotswood, is appealing for souvenirs of the College and of the station. Among the College's possessions already held are the Lewis gun used by Capt. Albert Ball, V.C., and a parachute flare carried by Alcock and Brown.

TRANS-PACIFIC LOGISTICS.—A Douglas C-133A Cargomaster of MATS arrived at Tachikawa air base, Japan, recently on its first flight to the Far East.

Air Transport

Reintroducing Far Eastern Comets

This report from JOHN FRICKER, *who has been flying with B.O.A.C. on the first Comet 4 proving flight to Tokyo, describes the Corporation's plans for the Far East and the competition which will soon be met over this route.*

WHEN B.O.A.C. begins to replace its Britannia 102s with Comet 4s on the Far Eastern route to Tokyo on April 1, the Corporation will gain with its jet services a lead of nearly six months over the other 10 or so competing companies operating along the same sectors. Qantas is due to introduce its Boeing 707s on the Kangaroo route in about September, slightly before the extension of the B.O.A.C. Comet service to Australia, and Pan American will then lead the foreign services almost immediately into the battle of the big jets along the lucrative Far Eastern routes.

Although relatively small, the B.O.A.C. lead is, therefore, invaluable, particularly as much of the traffic along this route is seasonal. Summer is the time for many British business residents in the Middle and Far East to return home on leave, or for their children in the U.K. to fly out on school holidays, and to the natural national preference of these passengers will be added in many cases the habit of travelling by Comet.

Compared with the present elapsed-time schedule for the Britannia, of some 40 hours between London and Tokyo, the Comet will probably take less than 30 hours over the same route, and stopping at the currently used transit points. Starting with four services per week and increasing to five from July, the Comets will call at Zurich, Beirut, Karachi, Delhi, Calcutta, Bangkok, Hong Kong and Tokyo with alternative stops on some flights at Frankfurt, Rome, Teheran and Rangoon.

Stepping-up the Frequencies

In May, additional Comet services will start to Hong Kong with two flights per week, increasing to three in July and routed via Rome (or Zurich), Beirut, Bahrain, Bombay, Colombo and Singapore. With the addition of two services per week from London to Singapore in August this year, plus the five on the Australian route in late 1959, there will be no fewer than 15 Comet flights per week along the Far East trunk route by 1960.

This very high mean frequency of about two flights per day will provide B.O.A.C. with an additional selling point, and is an attractive counter to the slightly faster schedules offered by the bigger jets of competing companies. As these have more than twice the capacity of the Comet they will be operated at a lower frequency. When Qantas, for example, begin replacing their L-1049Gs with Boeing 707s, the Far Eastern services will probably be reduced from four to three per week, whereas B.O.A.C. are adding a service to their present four-times-weekly Britannia schedule.

While discussing the relationship between frequency and capacity, it is salutary to consider the impact resulting from the operation, by late 1960, of big jet aircraft by the six major competitors of B.O.A.C. along the Far Eastern routes. At the moment, there are about a dozen airline companies flying scheduled services along this route, making 60-70 flights per week each way and offering between 3,500 and 4,000 seats.

When half of these companies virtually double their seating capacity by introducing the big jets in 1960, even while reducing frequencies by perhaps 25%, passengers must be found in substantially increased numbers if economic load factors are to be achieved. With the recent decline in World passenger-traffic growth, however, this is obviously going to be no easy matter. Nor may it be practical, with the big jets, to pick up passengers by increasing the number of transit stops along the route, since they might be operating below their economic stage-lengths and may also have difficulty in operating from some of the smaller airfields.

These problems are by no means insoluble, but, with the Comet, they fortunately do not arise. And while the big jets will be happier on the westbound services of the Far East route, where longer sectors may be flown to get passengers rapidly from Asia to Europe, the Comet has sufficient flexibility to offer similar advantages. The de Havilland demonstration flight late last year showed that, with a slight reduction in payload, the Comet could fly from Hong Kong to London with stops at only Bombay and Cairo (or Beirut) in an elapsed time of 18-20 hours. In normal commercial operations, this could result in a journey-time of less than 24 hours.

With the all-out emphasis on speed, the leisurely days of air travel—typified by the flying-boat—have gone for all time. With night stops a thing of the past (they defeat the purpose of air travel but, more important, are too expensive), it is worth sparing a thought for the present-day passenger who sits immobile in his aluminium tube during a complete rotation of the earth, while relays of air crew (changed like polo ponies as they become fatigued) minister to him with their specialist rites.

Fortunately, the Comet offers as comfortable an immobility as has yet been devised, and its high speed restricts the longest period of Eastern contemplation to a little more than three hours. To fulfil the needs of most transit stations the aircraft of the Far East fleet are furnished with 20 first-class seats in the forward cabin and 43 tourist seats in the rear. An exception to the rule among the transit points is Calcutta, where, in the summer season, first-class passengers outnumber tourists by 2 : 1 on the westbound services, but they can still be fitted in with the general arrangement.

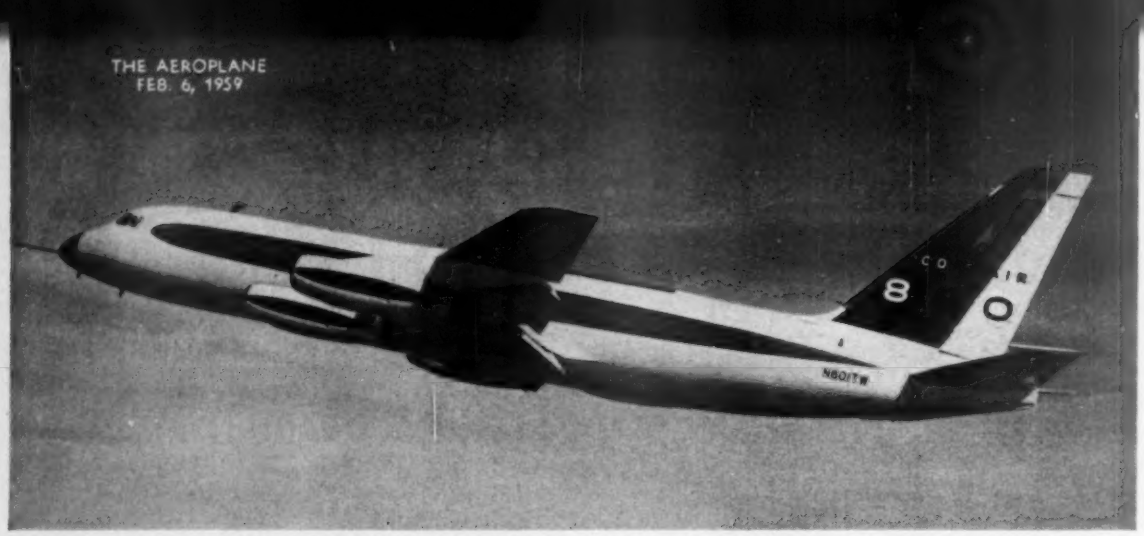
Proving flights for the April services began on January 21, when the third B.O.A.C. Comet 4, G-APDC, left London Airport for Tokyo. A further five route training flights to Japan are due by the end of March for crew familiarization and include visits to all the alternates for the Comet along the route, in addition to practice let-downs to the main transit airfields. All the pilots for these services are familiar with the route, and many had considerable flying experience on the Comet 1s.

Because of the provision of slip crews along the route (three complete crews, each of four flight personnel, being required to complete the London-Tokyo sectors), B.O.A.C. have had the formidable training task of qualifying the 261 Comet pilots and 130 crews. This requirement is for the 19 Comet 4s ordered by B.O.A.C., the delivery of which is due for completion by late 1959. When the Far Eastern services start in April B.O.A.C. will have received from de Havilland nine Comet 4s which will also share the work on the North Atlantic route. It is obvious that the planned utilization of 3,800 hours per annum per aircraft is necessarily realistic.

Few major problems are likely to be encountered on the

The third production Comet 4, G-APDC, is seen here on the apron at Yesilköy Airport, Istanbul, on the outward part of the proving-flight journey to Tokyo which will be the subject of a later article.

Photograph copyright "The Aeroplane"



FIRST FLIGHT.—The Convair 880 made its first flight from Lindbergh Field, San Diego, on January 27, in the hands of chief engineering test pilot Don Germeraad and a crew of five. After a 74-minute flight, the Convair 880 landed at the U.S. Naval Air Station on North Island, in San Diego Bay, where it will be based for the first 10 hours' flying.

proving flights with an aircraft which, since its original appearance, in much less modified form, nearly 10 years ago, has accumulated about 65,000 hours of flying. Over half of this total was achieved by B.O.A.C. on the first Comet 1s.

With its considerable power excess and low wing-loading, the Comet 4 has surprisingly similar airfield requirements to earlier piston or turboprop-powered transports. Even in critical tropical sectors of the Far Eastern route, and with existing runways, there are few airfields where restrictions are imposed on Comet operating weights or conditions during the summer. This is also before the introduction of reverse thrust to the Comet, which is mandatory for only one airfield along the route—at Kuala Lumpur, in Malaya.

Thrust reversers, which have been extensively test-flown on the Comet, will be fitted to the outboard Avon 524s from about the tenth production aircraft, in mid-1959, and provision is already made for their installation in existing aircraft. The exhaust louvres above and below the centre of the engine nacelles are at present blanked off by stiffened metal panels.

Each thrust reverser gives about 50% effective reverse thrust at any given r.p.m. from the two 10,500 lb. Avons, although initially only up to the maximum continuous power setting of 7,550 r.p.m. Reverse thrust control will be by aft movement of the throttles through a gate. Use of reverse thrust is not considered when calculating accelerate-stop distances, but is included when estimating runway requirements for landing. It will, of course, also reduce wear and tear on the brakes.

Since the Comet's runway requirements are so relatively modest—and many of its transit airfields are being extended for the operation of bigger jets—the main scope for improvement when regular services begin to the Far East will be in the air traffic control and navigational procedures. With these, B.O.A.C. must necessarily blaze the trail. Hitherto, military control centres have frequently taken over *en bloc* altitudes above 25,000 ft. in certain areas for jet traffic, but it is essential that the civil jets be given clearance for their optimum operating heights. For example, a Comet cruising 4,000 ft. below its best altitudes uses, during a five-hour sector, about one ton more fuel than it should, or the equivalent of 10 passengers and their baggage.

Another problem more specifically concerned with the Far East is the absence of navigational aids in some of the more remote sectors. Europe is well provided with VOR beacons, which are the primary aid, but between Turkey and Pakistan, for example, there are, literally, only one or two M/F beacons. These and other factors involved in Comet operations to the Far East we hope to discuss in greater detail in a subsequent article.

Viscounts on the Market

VICKERS Viscounts were offered for sale through the Aircraft Exchange for the first time in its third week of trading. The third *Market Report* records four Viscount 707s for immediate sale at an approximate price of $532,000 each ($505,000 adjusted for overhaul state). These are the original Aer Lingus Viscounts, which are being replaced by Viscount 808s and F-27s (see THE AEROPLANE for January 30, pp. 122-124).

More bids are again recorded in the third *Market Report*, principally for Convairs and DC-3s. The DC-6A appears among the aircraft on offer for the first time, three being available for lease at $30,000 a month each.

In addition to the new aircraft prices listed in our issue for January 23, the *Market Report* now records the DC-8 price as $5,200,000, making it the most expensive of all the turbojet transports now available.

Towards the Automatic Landing

THERE is one specially important feature in the recently issued IATA report* summarizing the technical conference discussions on the prospects of automatic landings for the airlines. This is the way in which nearly all those taking part stressed the vital necessity for the pilot to be able to handle a missed automatic approach without undue strain or effort.

Putting the problem in the words of the representative of the R.A.F. School of Aviation Medicine, the whole crux of the issue is whether the airlines can sell to the airline captains whatever system they decide to use; unless they can do so the airlines are wasting their time. This successful selling depends on the pilots' complete acceptance of the adequacy of the monitoring system used.

The report is a most thorough document in which 20 pages are devoted to a summary of the discussions and 195 pages to appendices in which 13 papers submitted to the conference are reproduced. These papers, mostly illustrated, cover various aspects of the problems involved in providing better ILS results, discuss automatic control and instrumentation generally, and provide descriptions of the systems developed by the U.K. Blind Landing Experimental Unit and by the U.S. Bell Aircraft Corporation. The B.L.E.U. system has already been described (see THE AEROPLANE of October 17, 1958, pp. 591-593, and January 23, 1959, p. 103); the self-contained, ground-based Bell system, which has, so far, been no more than broadly described, will be the subject of an article in a future issue.

As explained in a short reference to this IATA report in the issue of January 16 (p. 64), the general opinion of the conference (which was attended by representatives of 24 airlines and 40 manufacturers and organizations) seemed to be that progress in this field must be evolutionary rather than revolutionary. In other words, it was generally supposed that future automatic landing systems for civil use were likely to be based on the use of improved ILS, autopilot couplers and equipment which is already in use in one form or another.

The first part of the summary of the discussions is, therefore, devoted to the limitations of present ILS and to the means by which its performance can be improved—and particularly so at

(*Continued on page* 149)

* "Instrument Approach and Landing": A summary of the discussions on this subject at the 11th annual technical conference of IATA at Monte Carlo in September, 1958. The Technical Secretariat, International Air Transport Association, Terminal Centre Building, Montreal 3, P.Q., Canada.

Firestreak—a guardian of peace

DE HAVILLAND PROPELLERS LIMITED HATFIELD HERTFORDSHIRE

HAWKER SIDDELEY BREAKS PRODUCTION RECORDS WITH NEW AIR FREIGHTERCOACH, FROM "GO AHEAD" TO FIRST FLIGHT IN 28 MONTHS

The Armstrong Whitworth Argosy is the world's first pressurised turboprop freighter-coach. Never before in Britain has such a large and complex aircraft made its first flight so soon after the decision to go ahead —only 28 months. This is further proof of Hawker Siddeley's unrivalled reputation in the British aircraft industry, not only for high quality craftsmanship, but ability to meet and beat production schedules. The Argosy ushers in a new era of "flying without frills". It offers 300 m.p.h. economical air transport for freight and coach-class passengers. With its capacity for 13½ short tons, full-width doors and quick-loading system, it reduces turn-around time and freight rates to a minimum. The Argosy can be in service on the world's air routes by 1960.

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LTD.

Baginton, Coventry, England / Member of Hawker Siddeley Aviation Division

THE ***Argosy*** ... BRINGS THE COST OF AIR FREIGHT DOWN TO EARTH

VICKERS VIEW.—Another view of the Vanguard on one of its early test flights from Wisley. The work of Vanguard testing is being shared by six Vickers staff pilots—Jock Bryce, Brian Trubshaw, Bill Aston, Dickie Rymer, Staff Harris and W. D. Jarvis.

short ranges and thus over the most critical period of the approach. The second part deals with autopilots, couplers and flight-deck instrumentation, with special reference to the means by which the autopilot-coupler complex can be made "fail-safe"—probably by "redundancy" methods. As one speaker put it, we "can expect within the next few years to see equipment in service capable of not merely detecting its own faults but also inactivating the faulty equipment and maintaining continuity of operation on a fall-back basis automatically."

The really valuable discussions in the report, however, are centred around the means of pilot supervision and emergency take-over.

For fully automatic approach and landing, the pilot needs, the report says, two broad types of information:

(a) During a normal approach, he needs the information which will *truthfully* assure him that the approach is normal. For this purpose it is not sufficient that he be shown the same demands that are fed to the autopilot; he must at least be able to view the total situation and exercise judgment about whether the indicated demands are appropriate to it.

In general, a pilot must be able to judge demands by referring to situations and to judge responses by comparing them with demands, though a good case has been made for this second function to be automatic. . . .

(b) When some abnormality develops, either in the equipment or in the progress of the approach, it is not sufficient for the pilot to know that there is an abnormality; he must receive as clear an indication as possible of what to do about it. In the case of a failure for which it is not possible to indicate definite action, the nature and/or degree of failure must be made immediately evident. . . .

Instrument low approaches should not be continued beyond: (a) that height at which adequate visual guidance must be attained to enable continuation of the approach and landing; or (b) the minimum height from which an overshoot procedure can be safely executed.

Normally, the critical height is determined on any approach by the conditions influencing either (a) or (b) according to the particular circumstances, whichever is the first encountered.

Under present operating circumstances, the report continues, taking into account aircraft performance, instrumentation, manœuvrability, the reliability and adequacy of the let-down aid, and the type of information derived, the condition described in (a) is reached first. This height may be revised upward according to the number and degree of the many variables influencing the successful execution of approach.

The requirement included in condition (b) generally obtains at a lower height, since the necessity for maintaining precise alignment becomes secondary at the time of initiating overshoot action. However, the process of altering the configuration of the aircraft progressively while on instruments at low altitude imposes a critical height factor determined by such considerations as acceleration qualities, performance, and disturbances in stability caused by alteration of configuration from the approach to the climb condition. . . .

In order to reduce approach limits, the report states, attention must be given to the following: (a) cockpit design to minimize movement of the pilot's head, hands and eyes; (b) improvement to mode instrumentation in order to indicate aircraft trim, configuration, etc.; (c) proper planning of the size and position of autopilot controls and the controls of aircraft power and configuration, so that they are all within easy reach of one hand; (d) increase in the sensitivity of air speed information; (e) careful design of levers and switches combined with optimum location in the cockpit; (f) superimposition of command and position display; (g) better altimetry; (h) fully automatic overshoot, including configuration and power change, initiated by one pilot action; (i) multiplex (at least duplex) autopilots in order that failure be passive; and (j) manual override of the autopilot without the necessity for completely switching out all autopilot control functions. . . .

Fully automatic missed approach will, the report points out, need to accompany automatic landing, if it does not precede it, and should be usable as late in the approach as touchdown. Such features as automatic control of heading, height and climb will become desirable as minima are progressively lowered. Complete or partial automatic overshoot is now technically feasible, but a great deal of thought will have to be given to the programming of power, drag, pitch and configuration changes, as well as the factors in the previous sentence. Furthermore, it must be decided whether automatic overshoot is to be automatically initiated under certain circumstances or to be used only as the result of the pilot's judgment.

In addition to the comment mentioned in the second paragraph of this summary of a summary, the School of Aviation Medicine representative (Gp. Capt. Ruffell-Smith) had a number of other pertinent points to make on the papers and discussions. Among these the following can be usefully quoted:

Only the minimum number of values essential to safety should be monitored, for it must be realized that the more values there are the less often they will be sampled. . . .

The use of audio-displays should receive careful consideration, particularly for indicated airspeed and malfunctions. Auditory information can produce the fastest choice reaction. As the audio-channel is the last to go in anoxia and anæsthesia, it is probably the last to suffer deterioration due to fatigue. . . .

Remote computers are "not on" until data links between aircraft and the ground are less liable to interference; it would be as if man had to carry his brain around on a push chair.

"Provided we achieve certainty of the input information by duplication, I would suggest," he said, "that the way to get reliability in the rest of the control and computing system is to have one really good serviceable component. In man, heart, brain and liver are remarkably reliable; duplicated organs seem only to occur when they are more liable to failure."

The degree of confidence needed for auto-landing equipment is a whole order of difference from that required for auto-coupling; it must be at least as good as that afforded to a captain when monitoring a visual landing by his co-pilot. But even when all is said and done, one must never forget that the automatic-landing computer will have no fear of death.

ELECTRA EXPEDITER.—American Airlines is using pre-loaded containers to speed the loading and unloading of passengers' baggage in its Electras, which went into service between New York and Chicago on January 23. Four bins are carried in the forward baggage hold.

Competition in Canada

THE decision of the Canadian Air Transport Board—recorded in last week's issue, p. 116—to permit Canadian Pacific Airlines to operate a transcontinental service in competition with Trans-Canada Airlines is the culmination of a long struggle.

Since the Canadian Minister of Transport announced, on February 7, 1958, a change in government policy, many thousands of words have been spoken and recorded at successive hearings by the A.T.B. and the final result, so far, gives the outsider the impression that a mountain has laboured to produce a mouse. However, the daily Montreal-Toronto-Winnipeg-Vancouver rights will be valuable, as a start, to C.P.A., though the airline has registered particular disappointment at not being allowed to include a traffic point or points in Alberta.

Soon after the policy change was made known (see THE AEROPLANE of March 14, 1958, p. 350, for details of the changes and prospects) C.P.A. announced its intention of applying for three transcontinental and two intermediate connecting services over the route. These services were designed to serve Calgary, Saskatoon, Edmonton and Regina, in addition to Vancouver, Winnipeg, Toronto, Ottawa and Montreal. During the hearings—which followed the publication of an independent report, produced by Mr. Stephen Wheatcroft, the airline economist, for the Minister of Transport—the C.P.A. proposals were consolidated and applications were finally made for daily services over three routes between Vancouver and Montreal. Only one of these has now been approved; the other two proposed services took in Edmonton and Ottawa, and Calgary, Winnipeg and Ottawa respectively.

Mr. Wheatcroft's report (summarized and commented upon in THE AEROPLANE of August 22, 1958, p. 257) was, on the whole, cautious about the economic prospects of competition over the trunk routes—though admitting that such competition would be good for the passengers—but encouraged the idea of "incidental competition" whereby connecting services for the main terminals might be permitted.

The report showed, however, that the T.C.A. load factors had been too high and the frequencies too low and that lack of competition had delayed the introduction of cheap-fare services such as those offered in the U.S.A. It pointed out, too, that the T.C.A. services which made money were those across the North Atlantic, across the Continent and to Florida and the Caribbean; excessive competition on the transcontinental route might, therefore, reduce T.C.A.'s ability to break even.

Mr. Wheatcroft considered that, for 1959, the permissible economic maximum number of daily transcontinental limited-stop services should be no more than two or three. T.C.A. at present operates a one-stop service on six days of the week plus one more each week as an extension of the London-Montreal service. Other daily transcontinental services involve four or six stops.

So, subject to the Minister's original proviso that competition might be allowed where "economic conditions indicate that more than one operator can carry on successfully without Government subsidy," the limited approval now announced appears to follow the thinking in the Wheatcroft Report.

The new C.P.A. service, incidentally, provides a Canadian link between this carrier's Pacific services from Vancouver and its European services to Madrid and Lisbon from Montreal.

Independent Clarification

NOT a little confusion seems to have arisen over the use by the Hunting Group of the names of various of its companies in connection with the transport aircraft it owns and operates. The air transport operating company is, of course, Hunting-Clan Air Transport, Ltd., which (as explained in THE AEROPLANE for December 5) is a wholly owned subsidiary of Hunting-Clan Air Holdings, Ltd. This company, in turn, is owned in equal parts by the Hunting Group and, through Clan Line Steamers, by The British and Commonwealth Shipping Co., Ltd.

With the exception of the two Britannias, referred to below, the Hunting transport aircraft fleet—comprising Viscounts, Vikings, DC-6As and Yorks—operate in the Hunting-Clan livery. For administrative and other reasons, however, most of these aircraft are nominally owned by non-operating companies in the group. Thus, an examination of the current edition of the A.R.B.'s British Register of Civil Aircraft shows five Vikings and four Yorks registered to Hunting-Clan Airservices; a Viscount 732 and a DC-6A registered to Northern Aircraft Operating Co., Ltd., and a Viscount 732 (since destroyed) and a DC-6A registered to Clanair, Ltd.

The position of the two Britannia 317s is rather different. Although these also are registered to Clanair, Ltd., and are being operated by Hunting-Clan aircrew (see THE AEROPLANE last week, page 118) they have been finished in the colours of British and Commonwealth Shipping—which company, we understand, financed their purchase by Hunting-Clan. As is widely known, Hunting-Clan's plans to use these Britannias on their existing services to Africa or elsewhere have been thwarted by Ministerial decision.

Until the future of these aircraft has been decided, therefore, it was felt by the Group that they should not appear in H.C.A. markings. They are being used, meanwhile, for general charter flying as the opportunity arises, and one has recently been to the Far East, taking ships' crews to Bombay and Tokyo (via Nicosia and Bangkok) and returning with other crews from Hong Kong via Calcutta, Karachi and Istanbul.

Dart Overhaul at L.A.P.

BRITISH EUROPEAN AIRWAYS recently began the complete overhaul and the post-overhaul testing of Dart engines at its London Airport engineering base. It is the first British airline to overhaul Darts, of which it has more than 250 in service. Their overhaul at London Airport eliminates the time and cost of road transport to distant bases. This considerably reduces the number of spare engines needed, as fewer are in the "pipeline" at any time.

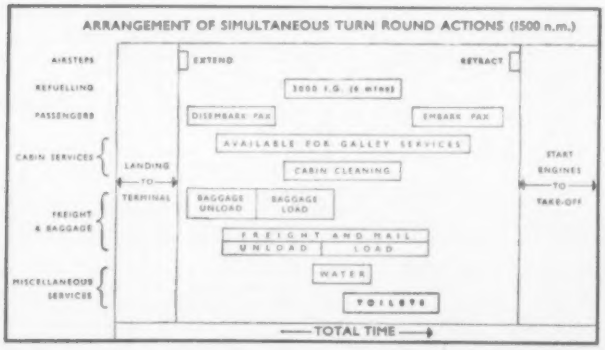
Dart engines are now being overhauled on a "pilot-plant" basis to gain experience. When extensions to the B.E.A. engineering base have been completed, very much larger engine-overhaul shops will come into use and B.E.A. will overhaul both the Dart engines of its Viscount fleet and the Tynes of its Vanguards. With the present plant two Darts per week are overhauled; eventually a total of 16 Darts and Tynes will be overhauled every week.

After their overhaul the Darts are run on an underground test bed, designed, manufactured and installed by Heenan and Froude, Ltd., where they are tested against a 2,500 b.h.p. dynamometer. This test-cell was built underground to reduce noise, but two additional test beds are to be built at ground-level next to the new engine-overhaul shop. Experience has shown that engine noise need not be a problem with ground-level test beds.

Overhaul lives for the engines of B.E.A. Viscounts are now 2,200 hr. for the Dart 506 and 2,000 hr. for the Dart 510.

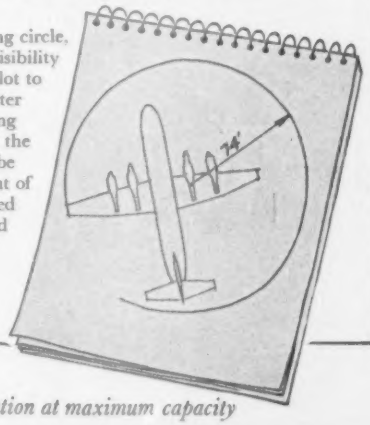
Yes, with the VANGUARD

Special design features of the Vickers VANGUARD cut time on the ground — and therefore operating costs — to a minimum. Cabin doors fore and aft, with built-in folding stairs, ensure rapid passenger handling. With their wide doors, the capacious freight holds permit simultaneous loading and unloading, and the large floor area allows spacing out of individual packages for rapid unloading at successive stops. All services are readily accessible, and the actual pressure re-fuelling for a 1,500-mile flight takes only six minutes. With its low tyre pressures, the VANGUARD does not have to wait to use a particular part of the apron. All this gives the VANGUARD more time where it should be — in the air! *It's the airline's airliner.*



For your notebook . . .

Minimal turning circle, and excellent visibility enabling the pilot to see both the outer engines and wing tips, mean that the VANGUARD can be taken in and out of the most crowded apron safely and quickly.



Maximum utilisation at maximum capacity

VICKERS VANGUARD

Four Rolls-Royce Tyne Propeller-Turbine Engines

VICKERS-ARMSTRONGS (Aircraft) LIMITED WEYBRIDGE SURREY

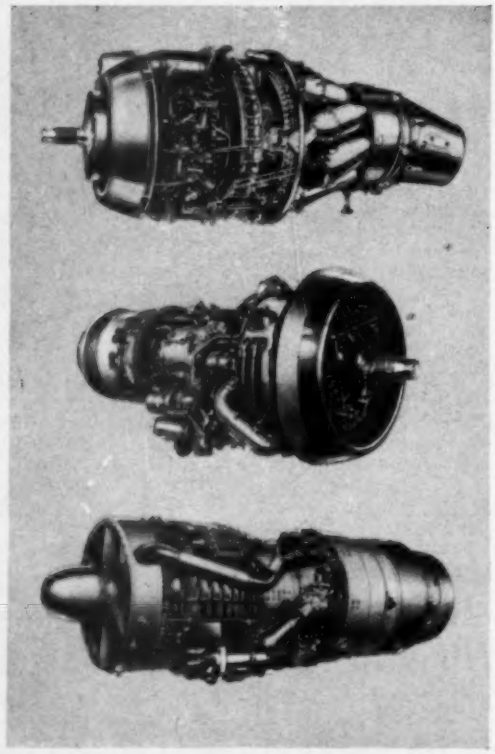
TGA AT529

A NEW ERA

THE ROLLS-ROYCE CONWAY BY-PASS JET ENGINE

has now been granted a full certificate of airworthiness by the Air Registration Board at a minimum rating of 17,000 lb. thrust. Conways are now being delivered to aircraft manufacturers.

ROLLS-ROYCE EXPERIENCE IN THE AIRLINE OPERATION OF GAS TURBINES IS UNIQUI



THE DART

—the first, and for four years the only prop-jet in airline service has flown over 6,000,000 hours. The Dart is currently operating at overhaul lives of up to 2,200 hours.

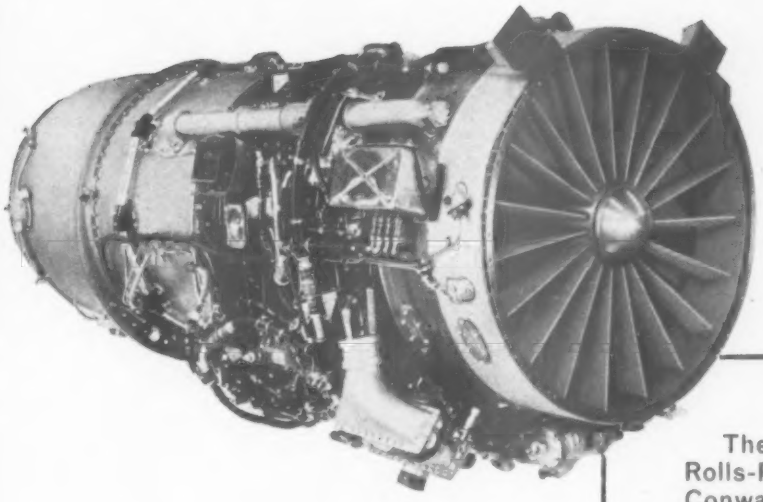
THE TYNE

—a most advanced prop-jet engine, is due to enter service in 1960 at ratings of 4,985, 5,525 and 5,730 e.h.p. It has a specific fuel consumption comparable with the latest compound piston engines.

THE AVON

—the first turbo jet on the North Atlantic route, and now in daily service, began scheduled operations with an approved overhaul life of 1,000 hours.

IN JET POWER



DEVELOPED FROM EXPERIENCE

The by-pass principle which Rolls-Royce have proved in the Conway engine is now accepted as the correct formula for all jet transport and for certain military applications.

The new RB.141 family of by-pass jet engines is based on seven years' development experience of the by-pass principle gained with the Conway and on six years' operation of other gas turbine engines in airline service. The first of this series has already been chosen to power the new British European Airways medium range jet airliner.

ROLLS-ROYCE ***GAS TURBINES***

ROLLS-ROYCE LIMITED, DERBY, ENGLAND

AERO ENGINES · MOTOR CARS · DIESEL AND PETROL ENGINES · ROCKET MOTORS · NUCLEAR PROPULSION

Jet Provost

The standard primary/basic trainer for the Royal Air Force

An intensive and thorough evaluation carried out with Mk.1 aircraft has paved the way to the current production version, the Mk.3. Refinements include hydraulically operated services, Martin-Baker ejection seats, wing-tip auxiliary fuel tanks and a one-piece moulded windscreen.

All Jet Provosts are powered by the Armstrong Siddeley Viper turbojet.

"The Aeroplane" photo

HUNTING AIRCRAFT LIMITED

A Hunting Group Company

LUTON, BEDFORDSHIRE, ENGLAND, AND AT 1450, O'CONNOR DRIVE, TORONTO, CANADA

POWERPLANT SURVEY

Physical Factors in Gas-turbine Evolution

Rocket Engine Developments

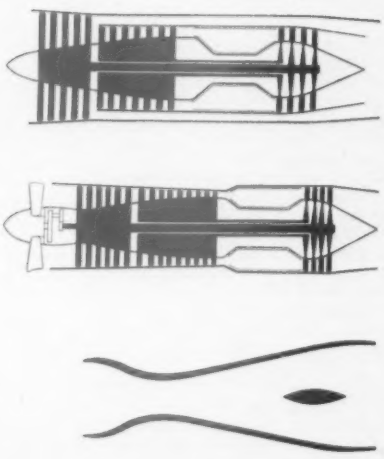
Gas Turbines for Special Duties

International Selection (gas-turbine drawings to scale)

Gas Turbine Facts and Figures (technical data)

The Noise Problem

Piston-engine Data



ALTHOUGH the design, development and manufacture of aero-engines has always formed an important specialist industry within the overall aeronautical scene, it has only been in the past decade or so that it has expanded, almost out of all recognition, to become a science in its own right. This expansion has sprung as much from internal development as from "customer" demands dictated by the stringent requirements in the competitive business of operating aeroplanes—whether it be for civil or Service rôles. The effect of the introduction of the gas-turbine engine as a powerplant for aircraft has become a matter of history; so also has its influence on airframe design and the consequent inter-relation between progressive aircraft and engine development. In much the same way the more recent introduction of the rocket engine in its various forms and its subsequent gradual refinement has brought about further extensions to the science of aeronautics—which has now reached into the realm of astronautics via the intermediate path of guided missile technology.

One of the outstanding recent powerplant trends has been the gradual demise of the large piston engine and the growing number of new turboprop engines. This has followed Britain's lead with the introduction of the Rolls-Royce Dart and the Vickers Viscount into airline service which brought air travellers the World over to expect the quietness and lack of vibration that results from turbine engines. Similarly, there have been corresponding noteworthy developments in the application of such powerplants to helicopters and here again the aero-engine industry in this country has shown the way towards the very large turbine-powered rotorcraft.

So far as turbojet engines are concerned, the most notable of recent developments has been the introduction of two large American turbofan engines. As pointed out on our correspondence page this week, however, it must be remembered that the two-tier ducted fan engine was invented by Sir Frank Whittle. Nevertheless, these new American engines represent the latest, and one of the most promising, attempts to solve what is, perhaps, the greatest of the present powerplant problems—the suppression of noise. British contributions, here, include the Conway by-pass engine which is to power some versions of the first generation of American turbojet airliners—and our own Vickers VC-10. A later Rolls-Royce by-pass engine is the R.B.141 destined for the new de Havilland D.H.121.

Small turbojets having a very high thrust/weight ratio are beginning to make their appearance both here and in the United States. These have particular application to VTOL aircraft, in the later drone aircraft for missile targets, and for the new generation of high-speed executive transports. There has also emerged recently a new range of small shaft-turbine engines principally for helicopters. And in another field altogether there is growing appreciation of the value of turbine engines as auxiliary powerplants for airborne and ground use.

Rocket powerplants are still sufficiently new for the developments in this field to be rather more far-reaching than is the case with the turbine engines. Here, perhaps, the most interesting trend has been the development of solid propellents that can rival the performance of liquids for certain applications. But this may well be a passing phase and the liquid propellent rocket engine will be, in the long run, the established powerplant for all but a few specialized duties.

All these trends are discussed in detail in the articles which follow in this special powerplant supplement. In addition there is a pull-out on which are illustrated, by means of scale drawings, 21 representative gas-turbine engines of particular significance and on the back of this pull-out are given the leading technical particulars of the World's principal gas-turbines. Piston engines are covered in a separate table; rocket data are to be found in the appropriate article. And to complete the coverage a number of photographs illustrate current internationally used engines.

Powerplant Survey . . . .

Physical Factors in Gas-turbine Evolution

by I. M. Davidson, B.Sc. (Eng.), A.F.R.Ae.S.*

LIKE all engineers, the aircraft gas-turbine specialist is squeezed between two sets of "forces"—ultimate physical limitations and user demand. Even in military aircraft the latter can depend in the final analysis upon public opinion, so these notes are concerned only with those physical barriers which have stood, and will stand, in the way of progress.

The Clearly Recognizable Limits

Initially, the aerodynamic problems, although taxing, were not the most troublesome. Centrifugal compressors and reaction turbines had been under development since the turn of the century, but there was no precedent for the combustion engineer and no selection of good, high-temperature blade materials. Hence, although Whittle contemporaneously developed the centrifugal compressor to a degree never before thought possible, the first dramatic advances came in the combustion and metallurgical fields. Of course, the required combustion intensities naturally were, and indeed still are, well below any absolute physical limits.

In practice a balance must be struck between chamber size and pressure loss, and between high combustion efficiency and wide stability limits; all of which so removes the practical problems from any ultimate barrier that one particular solution may be just as good as the next. Quantitatively, the trend has been:—

Best pre-Whittle practice, 0.1×10^6 C.H.U./hr./cu. ft./atm.
The first production engines, 1.0×10^6 C.H.U./hr./cu. ft./atm.
Current high-duty engines, 2 to $2\frac{1}{2} \times 10^6$ C.H.U./hr./cu. ft./atm.
Best full-scale research, 6×10^6 C.H.U./hr./cu. ft./atm.

The metallurgical development of turbine blade material is an interesting one because, significant as the gains have been in terms of material properties, they have been amplified in the hands of the engineer to produce quite outstanding advances in engine performance—the result of two physical limits converging in a single component.

When an improved blade material is offered it relieves the turbine disc in two quite different ways. The blades being slimmed, centrifugal loading of the rim is reduced and so is the heat soakage through the blade roots. In the early days, disc temperatures of over 450°C. were unavoidable and austenitic materials were obligatory. Now, with even higher gas temperatures, the disc designer can sometimes use a ferritic steel. Should he desire a choice of evils, that is; for one of the fields in which knowledge about the ultimate physical possibilities is still incomplete is that of plastic flow and thermal cycling in discs.

Since creep and fatigue at elevated temperatures are such formidable barriers, what is the chance of another big advance? In addition to the well-known ceramics there are the cermets, or sintered combinations of ceramic and metal, which are particularly intriguing because they can in principle be graded along a blade from pure ceramic at the tip to pure metal at the cooler, highly stressed root. But for the moment these all still suffer from one quite crippling ailment—sensitivity to mechanical and thermal shock.

With molybdenum-based alloys and the like, the big problem is oxidation in the gas stream. If this can be overcome—perhaps even by plating—these materials will offer roughly twice the strength of the best nickel-based alloys for a density increase of only 25%.

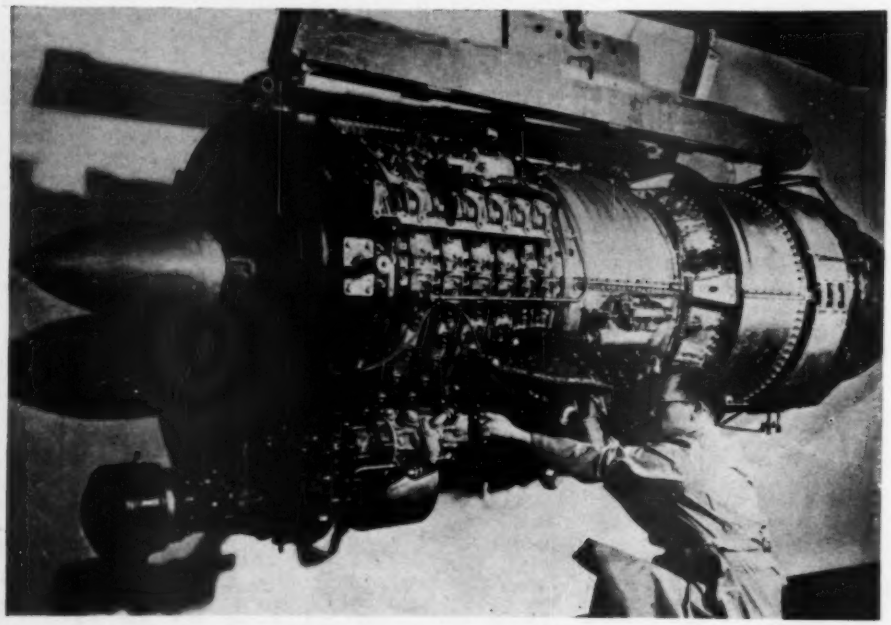
But, even so, it could be that, as with titanium in compressors, the new medicine will be a specific and not a panacea. Apart from cost, to make the turbine blades too slender could be to open the door to such aero-elastic evils as have so far possessed only the compressor.

The Vaguer Ills

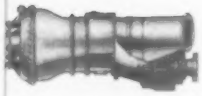
Compared with the turbine's evident mechanical barriers, the physical limitations, or rather diseases, of the axial-flow compressor are as the plague. This component of the modern engine comprises in effect a collection of small wings, each of them subject to the same sort of compressibility, stalling and aero-elastic troubles as any aircraft wing. Worse, since

(*Continued on page 159*)

* Of the National Gas Turbine Establishment.



The General Electric J79 turbojet has variable stagger on no fewer than seven of its compressor stator rows–the arrangement of which can be seen here. The stagger of a compressor blade is its angular setting, for the term pitch is used for the distance apart of the blades in a row.



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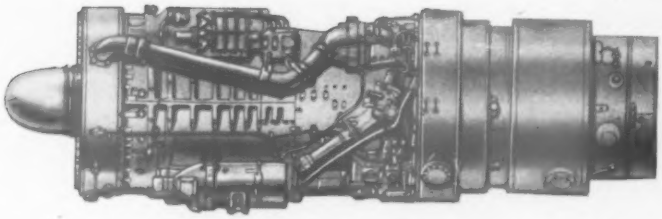
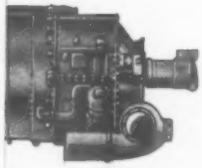
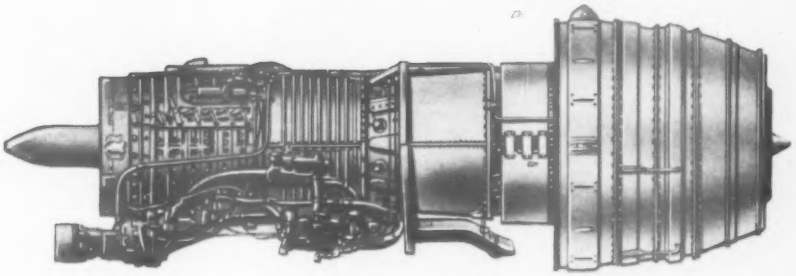


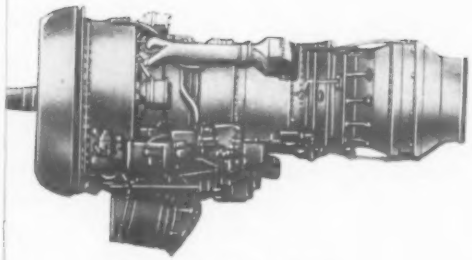
ROLLS-ROYCE AVON R.A.29



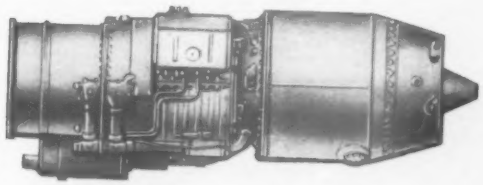
NG SIDDELEY P.181



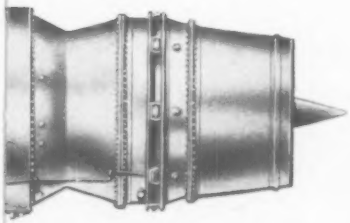
GENERAL ELECTRIC CJ-805-21



ROLLS-ROYCE TYNE R.Ty.1



BRISTOL ORPHEUS Mk.810



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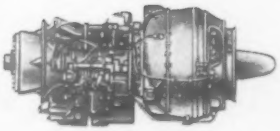

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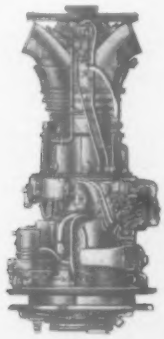

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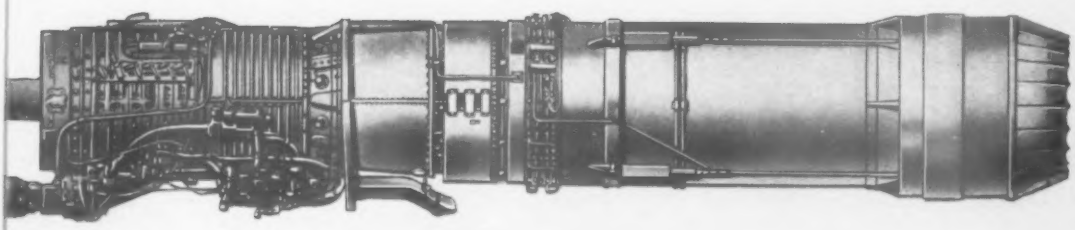
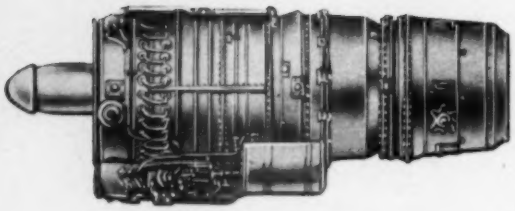


GENERAL ELECTRIC J79

Powerplant Survey . . . .

INTERNATIONAL SELECTION

These twenty-one gas turbine aero-engines have been chosen as representative of the current state of development. Each engine has its own particular significance whether it be the largest turbojet or the smallest shaft turbine. All these side views have been drawn to a common scale and as reproduced are approximately 1/36 full size.



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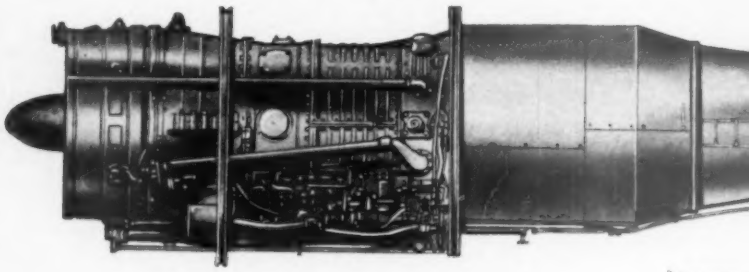
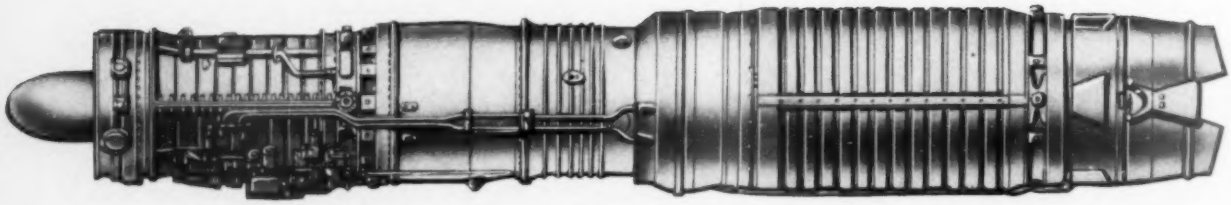
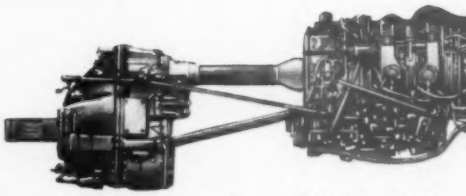


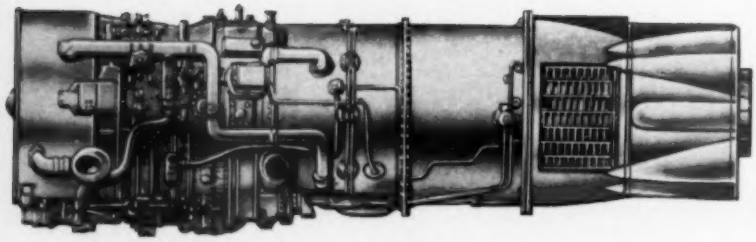
BRISTOL



SNECMA ATAR 9



ALLISON 501-13



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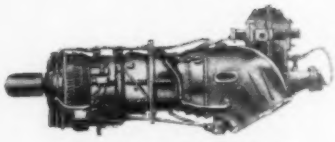
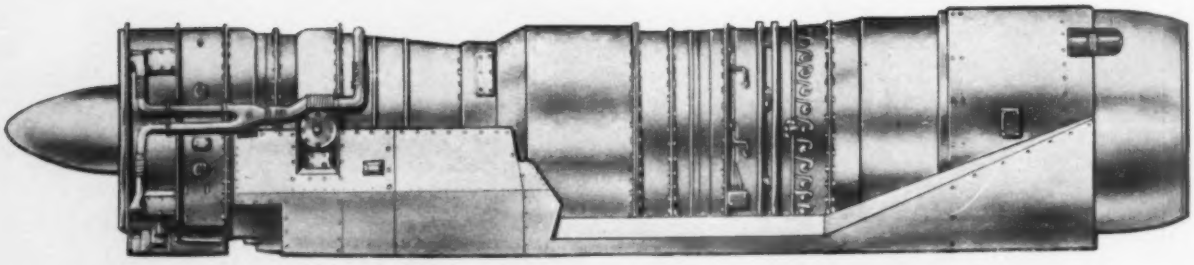
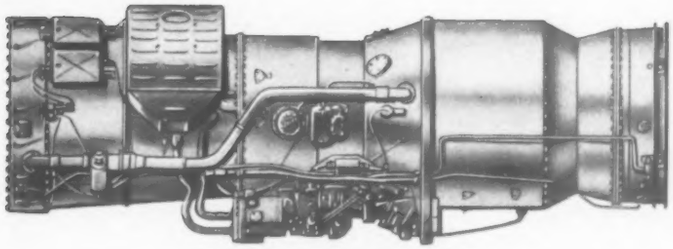


GENERAL ELECTRIC T58

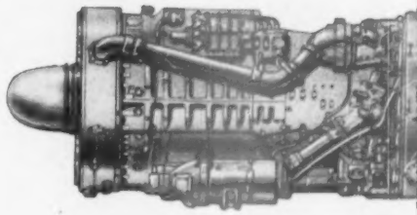


ORENDA ENGINES IROQUOIS



PRATT & WHITNEY JT4A-3

BLACKBURN A.129



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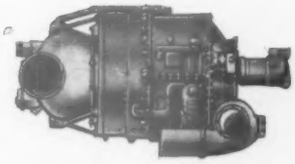
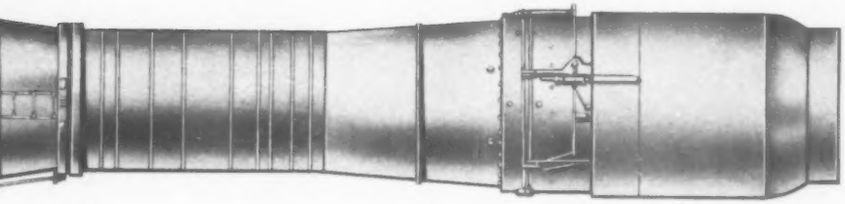
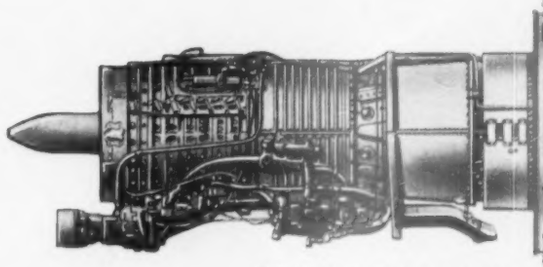


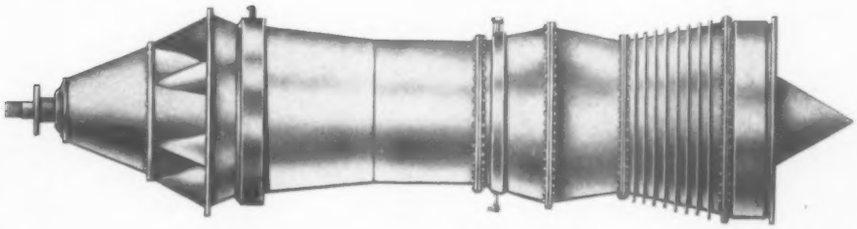
ARMSTRONG SIDDELEY P.181



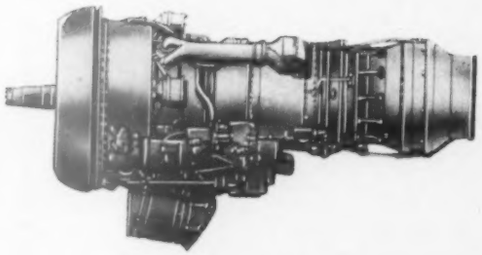
TOL OLYMPUS B.OI.7R



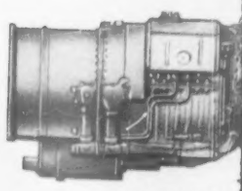
GENERAL ELECTRIC CJ-805-21



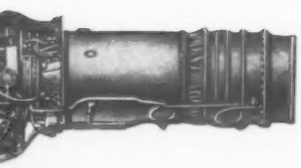
KUZNETSOV NK-O12M



ROLLS-ROYCE TYNE R.Ty.1

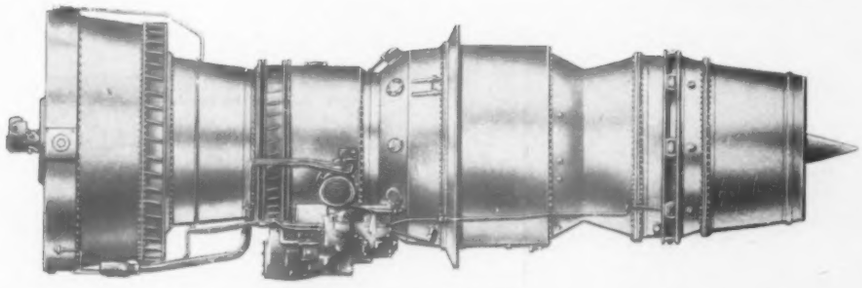


BRISTOL ORPH

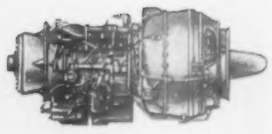


3

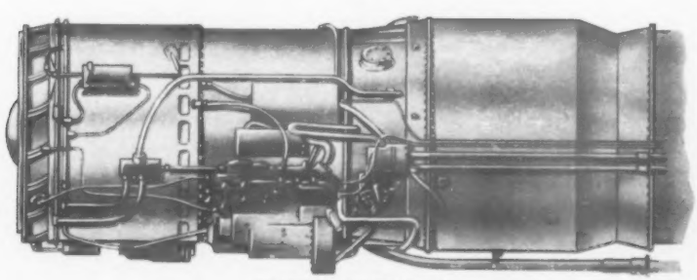
TURBOMECA BASTAN



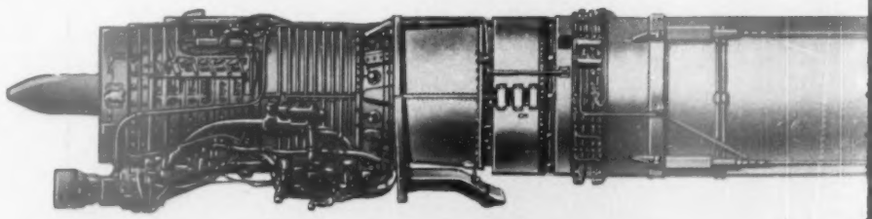
PRATT & WHITNEY JT3D-1



LYCOMING T53



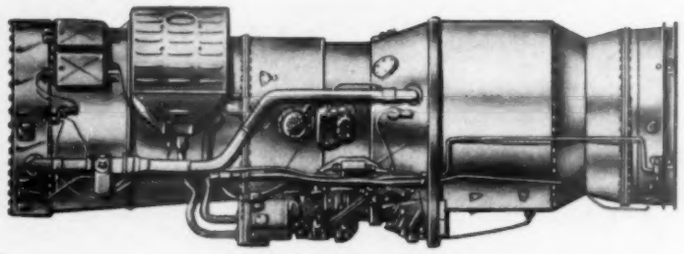
PRATT & WHITNEY J58



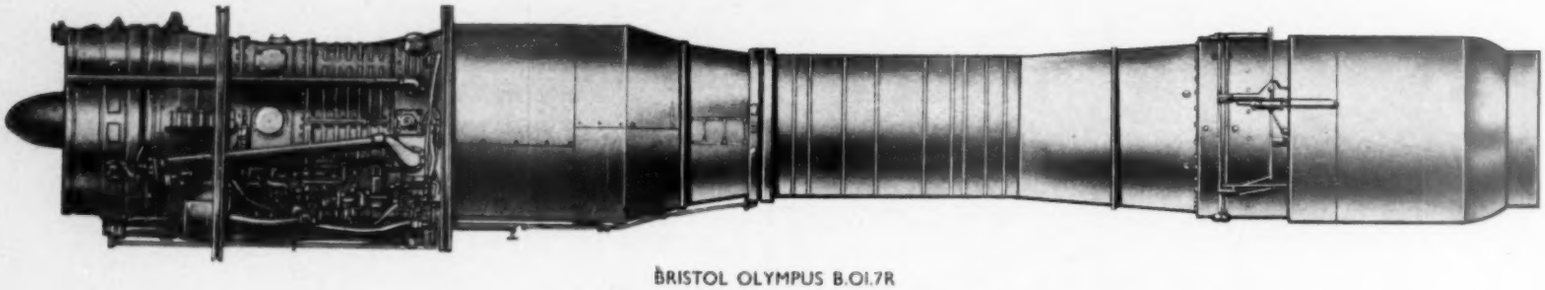
GENERAL ELECTRIC J79

AL SELECTION

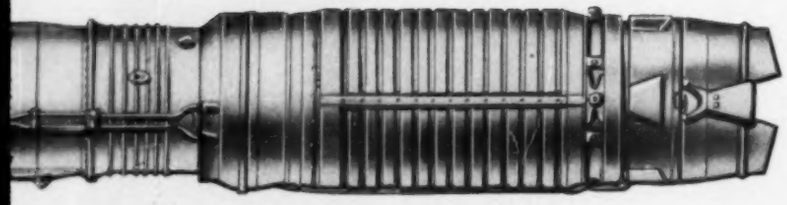
nty-one gas turbine aero-engines have been chosen as ive of the current state of development. Each engine has rticular significance whether it be the largest turbojet or t shaft turbine. All these side views have been drawn to scale and as reproduced are approximately 1/36 full size.



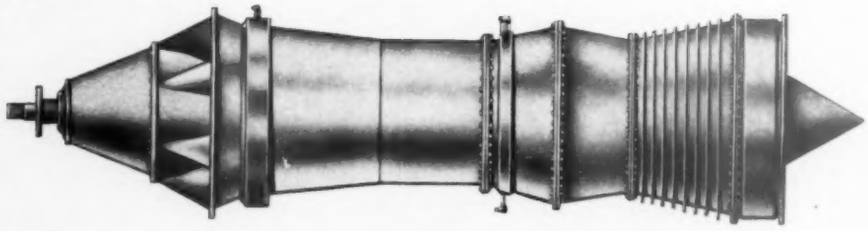
PRATT & WHITNEY JT4A-3



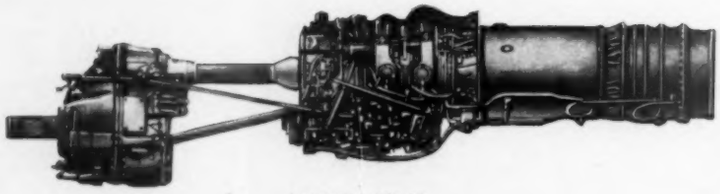
BRISTOL OLYMPUS B.OI.7R



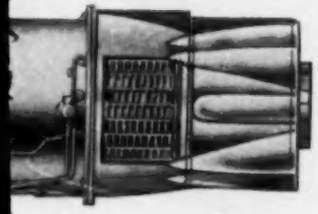
SNECMA ATAR 9



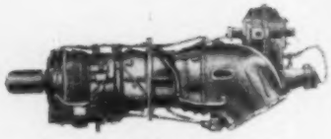
KUZNETSOV NK-O12M



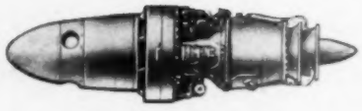
ALLISON 501-13



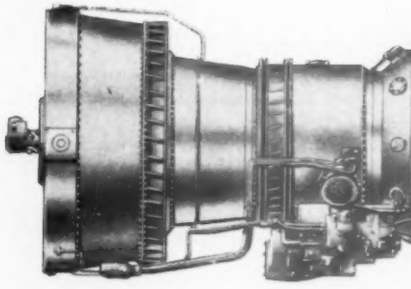
Y R.Co.10



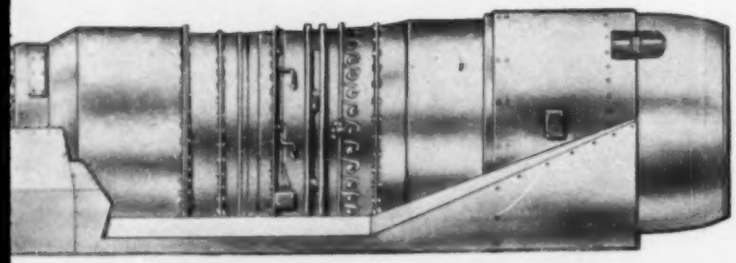
GENERAL ELECTRIC T58



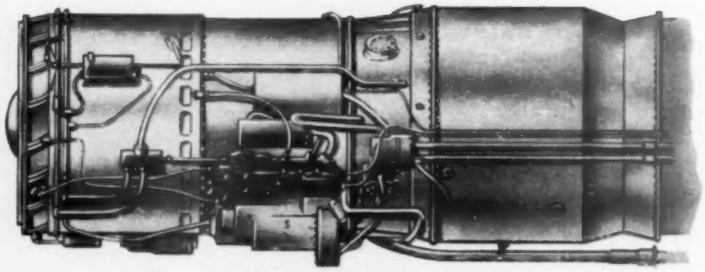
TURBOMECA BASTAN



PRATT & W

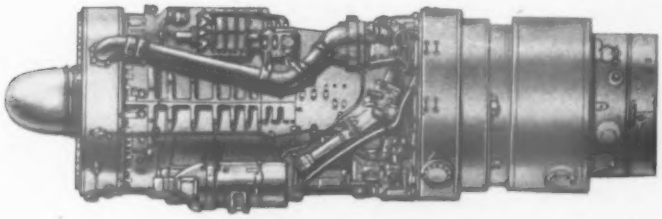


ORENDA ENGINES IROQUOIS

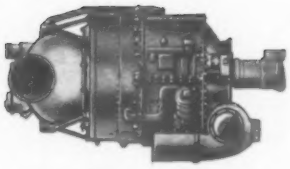


PRATT & WHITNEY J58

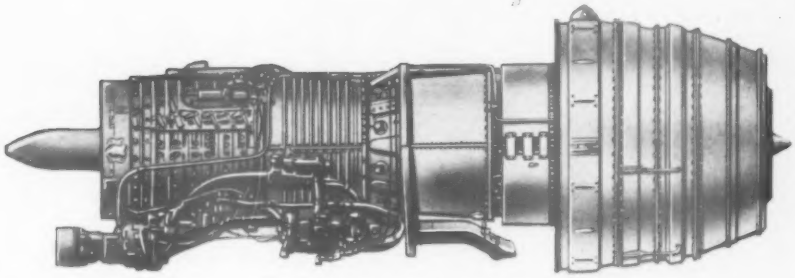
BLACKBURN A.129



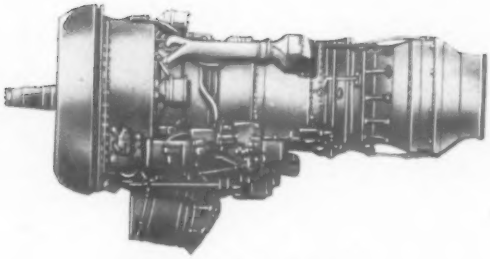
ROLLS-ROYCE AVON R.A.29



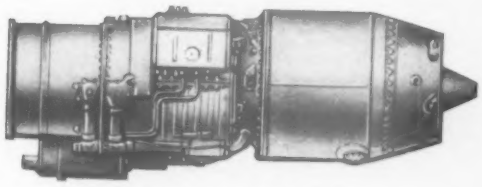
ARMSTRONG SIDDELEY P.181



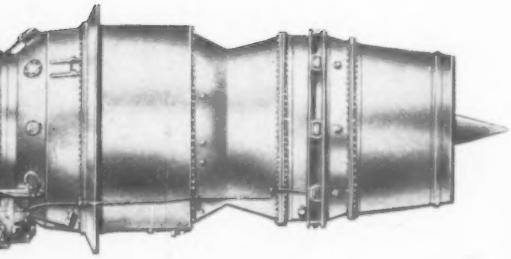
GENERAL ELECTRIC CJ-805-21



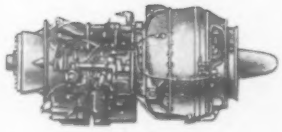
ROLLS-ROYCE TYNE R.Ty.1



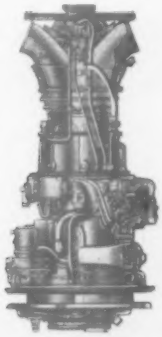
BRISTOL ORPHEUS Mk.810



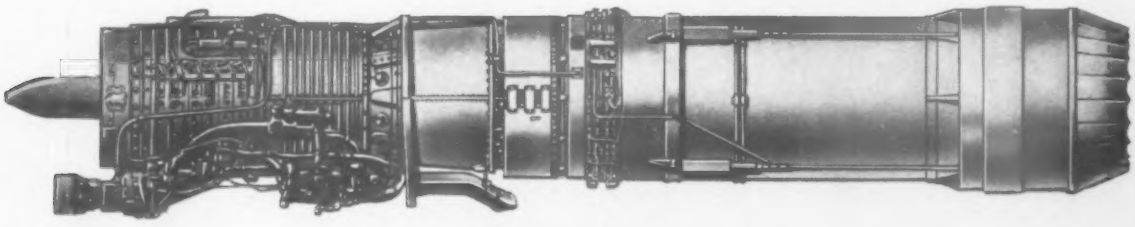
& WHITNEY JT3D-1



LYCOMING T53



NAPIER GAZELLE N.Ga.3

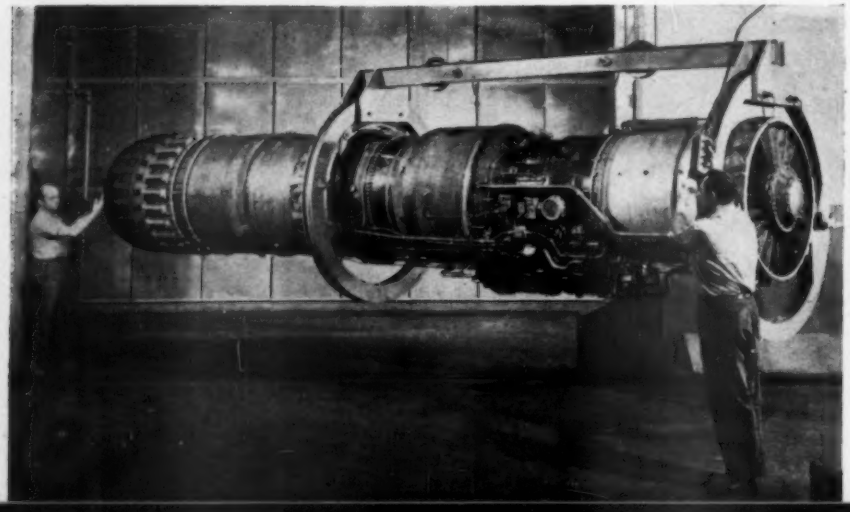


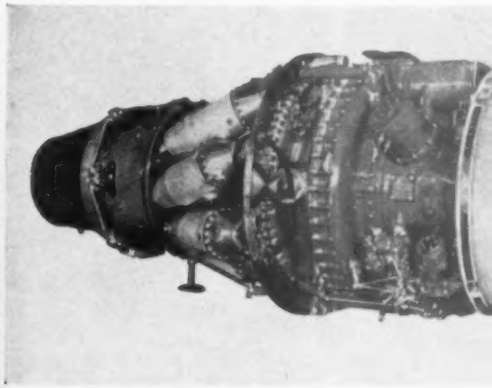
GENERAL ELECTRIC J79

Powerplant Survey . . . .

GAS T

Engine		Compressor				No. of combustion chambers	No. of turbine stages	Sea level static performance					
								Take-off					Ma
Make and name	Type	Type	Stages	Pressure ratio	Air mass flow			lb. th.	s.h.p.	e.h.p.	r.p.m.	lb./*/hr.	lb. th.
					lb./sec.								
CANADA													
Orenda Engines													
Orenda Series 14	Tj.	Ax.	10	6.1 : 1	130.0	6	2	7,500	—	—	7,800	0.997	N.A.
Iroquois	Tj.	Ax. x Ax.	N.A.	*8.0 : 1*	*335.0*	Ann.	N.A.	*28,000a*	—	—	N.A.	N.A.	N.A.
FRANCE													
Marcel Dassault													
R.7 Farandole	Tj.	Ax.	7	3.8 : 1	55.0	Ann.	1	4,080*a*	—	—	11,800	1.07	N.A.
Hispano Suiza													
R.854	Tj.	Ax.	7	4.8 : 1	57.3	Ann.	1	4,450*a*	—	—	12,000	2.00*a*	N.A.
Snecma													
Atar 8	Tj.	Ax.	9	5.2 : 1	150.0	Ann.	2	9,700	—	—	8,400	0.98	8,300
Atar 9	Tj.	Ax.	9	5.2 : 1	150.0	Ann.	2	13,250*a*	—	—	8,400	2.07*a*	11,800
Turbomeca													
Palas I	Tj.	C.	1	3.95 : 1	7.05	Ann.	1	353	—	—	N.A.	1.17	287
Marboré II	Tj.	C.	1	3.85 : 1	17.64	Ann.	1	880	—	—	22,600	1.15	795
Gabizo	Tj.	Ax.+C.	2	5.2 : 1	*42.0*	Ann.	1	3,395*a*	—	—	17,500	2.25	1,940
Bastan	Tp.	Ax.+C.	2	N.A.	N.A.	Ann.	2x1	145.5	750	805	33,500	0.64	N.A.
Turmo III	S.T.	Ax.+C.	2	*5.1 : 1*	*10.60*	Ann.	2x1	—	750	N.A.	34,500	0.77	N.A.
Artouste III	S.T.	N.A.	N.A.	N.A.	N.A.	Ann.	N.A.	—	600	N.A.	N.A.	N.A.	—
Palouste IV	G.G.	C.	1	3.7 : 1	2.71	Ann.	2	—	—	252	34,000	1.23	—
GERMAN DEMOCRATIC REPUBLIC													
Type 014	Tj.	Ax.	12	N.A.	110.0	Ann.	2	6,945	—	—	N.A.	0.85	N.A.
ITALY													
Fiat													
Type 4002	Tj.	C.	1	4.0 : 1	13.9	Ann. Rev.	1	716	—	—	25,000	1.18	N.A.
Type 4032	Tj.	Ax.	9	5.5 : 1	110.0	Cann. 10	1	5,950	—	—	8,200	N.A.	N.A.
Type 4700	G.G.	C.	1	4.0 : 1	10.4	Ann.	1x1	—	—	542	25,000	N.A.	—
JAPAN													
Nippon Jet-Engine Co.													
Model J3-1	Tj.	Ax.	8	N.A.	N.A.	Ann.	1	2,646	—	—	N.A.	N.A.	N.A.
UNITED KINGDOM													
Bristol-Siddeley Engines													
Viper Mk. 102 A.S.V.8	Tj.	Ax.	7	4.1 : 1	32.0	Ann.	1	1,750	—	—	13,800	1.12	1,475
Viper A.S.V.11	Tj.	Ax.	7	3.9 : 1	42.0	Ann.	1	2,460	—	—	13,400	1.11	2,020
Orpheus 701 B.Or.2	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	4,250	—	—	N.A.	N.A.	N.A.
Orpheus 801 B.Or.3	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	5,000	—	—	N.A.	1.06	N.A.
Orpheus 810 B.Or.3/5	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	5,100	—	—	N.A.	N.A.	N.A.
Orpheus B.Or.4	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	4,230	—	—	N.A.	0.96	N.A.
Orpheus B.Or.12	Tj.	Ax.	8	N.A.	N.A.	N.A.	N.A.	6,810	—	—	N.A.	N.A.	N.A.
Sapphire A.S.Sa.7R	Tj.	Ax.	13	N.A.	N.A.	Ann.	2	12,300*a*	—	—	8,600	1.20*a*	9,600
Olympus Mk. 201 B.Or.7R	Tj.	Ax. x Ax.	5x6	N.A.	N.A.	Cann. 8	1x1	24,000*a*	—	—	N.A.	N.A.	N.A.
Double Mamba A.S.M.D.8	Tp.	Ax.	11	5.85 : 1	2x21.0	Ann.	3	710	3,600	3,875	15,000	0.66	710
P.181 (helicopter)	S.T.	Ax.+C.	2+1	5.9 : 1	12.5	Ann. Rev.	2x1	200	1,020	—	20,000*d*	0.71	182
P.182 (fixed-wing)	Tp.	Ax.+C.	2+1	5.9 : 1	12.5	Ann. Rev.	2x1	200	1,100	1,175	20,000*d*	0.65	180
Blackburn													
Turmo 600	S.T.	C.	1	4.12 : 1	7.2	Ann.	1x1	N.A.	400	—	35,000	1.05	N.A.
Artouste 600 Bn.A.1	S.T.	C.	1	4.12 : 1	7.2	Ann.	2	N.A.	475	—	35,000	0.99	N.A.
A 129	S.T.	Ax.+C.	2+1	6.35 : 1	11.0	Ann.	2x1	N.A.	840	N.A.	35,000	0.77	N.A.
Palouste 500 Bn.Pe.1	G.G.	C.	1	3.88 : 1	2.71	Ann.	2	—	—	252	35,000	1.23	—
Proteus 765	Tp.	Ax.+C.	12+1	7.2 : 1	44.3	8	2x2	1,260	3,960	4,445	11,593	0.60	1,165
Proteus 770	Tp.	Ax.+C.	12+1	7.2 : 1	N.A.	8	2x2	1,260	4,130	4,615	N.A.	N.A.	N.A.
de Havilland Engine Co.													
Gyron Junior D.G.J.10	Tj.	Ax.	8	*7.0 : 1*	*150.0*	Ann.	3	*10,000*	—	—	N.A.	N.A.	N.A.
Gnome D.Ge.1	S.T.	Ax.	10	8.0 : 1	12.4	Ann.	2x1	—	1,000	—	19,500*e*	0.65	—
D. Napier and Son													
Eland N.El.6	Tp.	Ax.	10	7.0 : 1	31.0	6	3	700	3,230	3,500	12,500	0.60	625
Gazelle N.Ga.3	S.T.	Ax.	11	6.37 : 1	17.5	6	2x1	340	1,800	—	20,400	0.66	285
Rolls-Royce													
Avon R.A.21	Tj.	Ax.	12	6.4 : 1	124.0	8	2	8,000	—	—	8,100	0.93	N.A.
Avon R.A.24	Tj.	Ax.	15	N.A.	N.A.	Cann. 8	2	11,250	—	—	8,000	N.A.	N.A.
Avon R.A.28	Tj.	Ax.	15	*7.8 : 1*	*160.0*	Cann. 8	2	10,000	—	—	8,000	0.86	N.A.
Avon R.A.29 Mk. 522, 524 and 525	Tj.	Ax.	16	*8.7 : 1*	N.A.	Cann. 8	3	10,500‡	—	—	8,000	0.775	N.A.
R.B.108	Tj.	Ax.	7	N.A.	N.A.	*Ann.*	1	2,010	—	—	N.A.	N.A.	N.A.
R.B.141	B.P.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	12,000	—	—	N.A.	N.A.	N.A.
R.B.145	Tj.	Ax.	7	N.A.	N.A.	*Ann.*	1	2,750	—	—	N.A.	N.A.	N.A.
Conway R.Co.10 Mk. 505 and 507	B.P.	Ax. x Ax.	N.A.	N.A.	N.A.	Cann.	N.A.	17,000	—	—	N.A.	N.A.	N.A.
Conway R.Co.15	B.P.	Ax. x Ax.	N.A.	N.A.	N.A.	Cann.	N.A.	18,500	—	—	N.A.	N.A.	N.A.





TURBINE AERO-ENGINES—FACTS AND FIGURES

Engine		Compressor				No. of combustion chambers	No. of turbine stages	Sea level static performance									
								Take-off					Maximum continuous				
Make and name	Type	Type	Stages	Pressure ratio	Air mass flow			lb. th.	s.h.p.	e.h.p.	r.p.m.	lb./*/hr.	lb. th.	s.h.p.	r.p.m.	lb./*/hr	Len
					lb./sec.												
UNITED KINGDOM—Contd.																	
Dart R.Da. 3 Mk. 506	Tp.	C.	2	5.5 : 1	20.0	7	2	365	1,400	1,540	14,500	0.727	295	1,230*c*	13,800	0.79	95
Dart R.Da. 6 Mk. 510	Tp.	C.	2	5.5 : 1	20.0	7	2	370	1,600	1,740	14,500	0.69	320	1,400*c*	14,000	0.725	97
Dart R.Da.7/2 Mk. 526, 527 and 529	Tp.	C.	2	5.75 : 1	22.0	7	3	505	1,910	2,105	15,000	0.66	445	1,920*c*	14,400	0.745	97
Dart R.Da.10 Mk. 540	Tp.	C.	2	6.35 : 1	25.5	7	3	670	2,440†	2,660	15,000	0.64	N.A.	N.A.	N.A.	N.A.	98
Dart R.Da.11 Mk. 541	Tp.	C.	2	N.A.	N.A.	7	3	655	2,100	2,350	15,000	0.675	570	2,040*c*	15,000	0.70	98
Tyne R.Ty.1 Mk. 505	Tp.	Ax.×Ax.	6×9	13.0 : 1	46.0	Cann. 10	1×3	N.A.	4,500	4,985	15,250	0.50	N.A.	N.A.	N.A.	0.405	100
Tyne R.Ty.11	Tp.	Ax.×Ax.	6×9	13.0 : 1	N.A.	Cann. 10	1×3	1,290	5,030	5,525	15,250	0.48	N.A.	N.A.	N.A.	0.388	100
Tyne R.Ty.12	Tp.	Ax.×Ax.	6×9	13.0 : 1	N.A.	Cann. 10	1×3	1,120	5,300	5,730	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	100
U.S.A.																	
Allison																	
J33–A–41	Tj.	C.	1	4.25 : 1	87.0	14	1	4,600	—	—	11,750	1.14	4,600	—	11,750	1.12	N.
J71–A–11	Tj.	Ax.	16	8.3 : 1	160.0	Cann. 10	3	10,200	—	—	6,100	0.80	N.A.	—	N.A.	N.A.	N.
Model 250–B2	Tp.	Ax.+C.	7+1	N.A.	3.0	1 Flow	2×1	N.A.	250	N.A.	N.A.	0.70	N.A.	212	N.A.	0.73	38
T56–A–1	Tp.	Ax.	14	9.25 : 1	32.5	Cann. 6	4	726	3,460	3,750	13,820	0.54	N.A.	3,375*c*	13,820	0.46	N.
Model 501–D13	Tp.	Ax.	14	9.25 : 1	32.5	Cann. 6	4	726	3,460	3,750	13,820	0.54	702	3,094	13,820	0.555	N.
Model 501–D15 (T56–A–7)	Tp.	Ax.	14	9.25 : 1	39.0	Cann. 6	4	N.A.	N.A.	4,050	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.
Boeing																	
Model 502–10F	Tp.	C.	1	N.A.	4.24	2	1×1	—	320	—	N.A.	0.92	—	N.A.	N.A.	N.A.	N.
T60–2	Tp.	C.	1	N.A.	5.5	2	1×1	—	400	N.A.	N.A.	0.72	—	350	N.A.	0.76	—
Continental																	
J69–T–19B (Turboméca Marboré)	Tj.	C.	1	4.0 : 1	16.7	Ann.	1	1,060	—	—	21,250	1.27	860	—	20,000	1.25	44
Fairchild																	
J44–R–26	Tj.	C./Ax.	1	3.25 : 1	N.A.	Ann.	1	1,100	—	—	N.A.	1.30	N.A.	—	N.A.	N.A.	N.
General Electric																	
J47–GE–33	Tj.	Ax.	12	5.5 : 1	103.0	8	1	7,650*a*	—	—	7,950	2.00*a*	5,100	—	7,950	1.13	N.
J79–GE–1	Tj.	Ax.	17	12.0 : 1	162.0	Cann. 10	3	18,000*a*	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
CJ–805–3	Tj.	Ax.	17	12.0 : 1	162.0	Cann. 10	3	11,200	—	—	N.A.	0.8	N.A.	—	N.A.	N.A.	N.
CJ–805–21	Tf.	Ax.	17	12.0 : 1	N.A.	Cann. 10	3+Tf.	15,100	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
J85	Tj.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	2,450	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
J93	Tj.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
T58–GE–6	S.T.	Ax.	10	Over 8.0 : 1	12.4	Ann.	2×1	—	1,050	—	19,500*e*	0.67	—	900	—	N.A.	55
Lycoming																	
T53–L–1 (T53–L–3; Tp.)	S.T.	Ax.+C.	5+1	6.0 : 1	10.7	Ann. Rev.	1×1	102	825	866	25,240	0.673	96	770	N.A.	0.689	47
T55–L–1 (T55–L–3; S.T.)	Tp.	Ax.+C.	7+1	6.2 : 1	20.0	Ann. Rev.	2×1	190	1,600	1,676	18,100	0.648	168	1,325	N.A.	0.685	58
Pratt & Whitney																	
JT12	Tj.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	3,000	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
J57–P–19	Tj.	Ax.×Ax.	9×7	12.5 : 1	180.0	Cann. 8	1×2	12,100	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.	N.
J57–P–31 (JT3)	Tj.	Ax.×Ax.	9×7	12.5 : 1	180.0	Cann. 8	1×2	13,000	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.	N.
JT3D–1	Tf.	Tf.×Ax.Ax.	2×6×7	N.A.	430.0	Cann. 8	1×3	16,000	—	—	8,200	N.A.	9,800	—	N.A.	0.755	148
J75–P–5	Tj.	Ax.×Ax.	N.A.	12.5 : 1	260.0	Ann.	N.A.	24,500*a*	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.	N.
JT4A–3	Tj.	Ax.×Ax.	N.A.	12.5 : 1	260.0	Ann.	N.A.	16,800	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.	N.
J58	Tj.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	30,000	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
T34–P–3 and 7	Tp.	Ax.	13	6.7 : 1	67.0	Ann.	3	1,250	5,500	6,000	11,000	0.63	1,125	4,750	5,200	0.655	N.
T34–P–9W	Tp.	Ax.	13	6.7 : 1	67.0	Ann.	3	—	5,950	6,500	N.A.	0.60	N.A.	—	N.A.	N.A.	N.
Solar																	
YT62 Titan (constant speed—YT66 variable speed)	S.T.	C.	1	N.A.	N.A.	Ann.	1	12	55	N.A.	57,600	N.A.	N.A.	N.A.	N.A.	N.A.	N.
Westinghouse																	
J34–WE–46	Tj.	Ax.	11	4.35 : 1	N.A.	Ann.	2	3,400	—	—	12,500	N.A.	N.A.	—	N.A.	N.A.	N.
J54–WE–2	Tj.	Ax.	16	8.0 : 1	100.0	Ann.	2	6,500	—	—	N.A.	0.85	N.A.	—	N.A.	N.A.	120
J81 (dev. of R.R. Soar)	Tj.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	1,860	—	—	N.A.	1.27	N.A.	—	N.A.	N.A.	N.
Wright																	
J65–W–18 (A.S. Sapphire)	Tj.	Ax.	13	7.0 : 1	120.0	Ann.	2	10,500*a*	—	—	8,200	N.A.	N.A.	—	N.A.	N.A.	N.
U.S.S.R.																	
Klimov VK–1A (in MiG–17)	Tj.	C.	1	4.5 : 1	N.A.	9	1	7,590*a*	—	—	13,000	N.A.	N.A.	—	N.A.	N.A.	N.
Mikulin RD–3 (in Tu–104, RD–3M in Tu–104A)	Tj.	Ax.	8	6.8 : 1	278.0	Ann.	2	14,850	—	—	N.A.	0.90	N.A.	—	N.A.	N.A.	N.
Mikulin M–209 (in Tu–16)	Tj.	Ax.	8	N.A.	N.A.	Ann.	2	18,040	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.
Kuznetsov NK–4 (in Il–18)	Tp.	Ax.	14	6.5 : 1	N.A.	Ann.	3	N.A.	4,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.
Ivchenko (in An–10)	Tp.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.
Kuznetsov NK–012M (in Tu–114)	Tp.	Ax.	14	13.0 : 1	137.0	Cann.	5	2,645	12,000	N.A.	9,250	0.573	N.A.	N.A.	N.A.	N.A.	N.
Soloviev TB–2–BM (in Mi–6)	S.T.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	4,700	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.

Note.—Data in italics are estimated or unofficial. Abbreviations.—Ann., annular; Ax., axial; B.P., by-pass engine; C., centrifugal; Cann., cannular; G.G., gas generator turbine engine; Tf., turbofan; Tj., turbojet; Tp., turboprop; * lb. thrust, s.h.p., e.h.p. or g.h.p. as applicable to respective type of engine; † 3,200 mil. type test; *a*, *c*, e.h.p.; *d*, compressor r.p.m.; *e*, power turbine r.p.m.; *f*, with reduction gear; ‡ R.A.29/5, 13,300 lb.

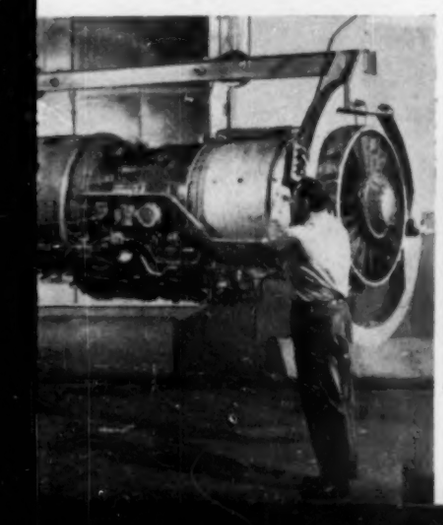
INTERNATIONAL ENGINES.—Left to right are the Pratt & Whitney J75 (U.S.A.), Rolls-Royce Dart R.Da.7 (U.K.), VEB Type 014 (German Democratic Republic), Bristol Proteus 765 (U.K.) and Mikulin RD-3 (U.S.S.R.).

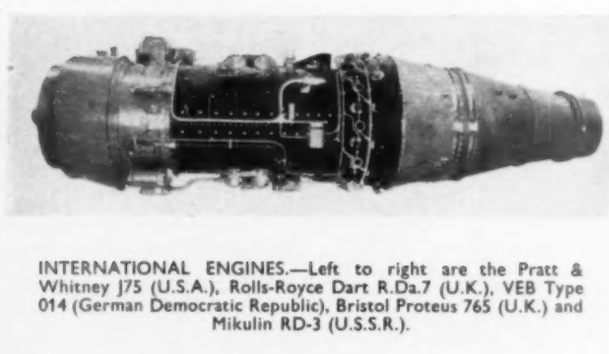
GAS TURBINE AERO-ENGINES—FACTS AN

Engine		Compressor				No. of combustion chambers	No. of turbine stages	Sea level static performance									Overall dimensions			Dry weight	Power/weight ratio
								Take-off					Maximum continuous				Length of engine	Length with ex. cone	Width or height		
	Type	Type	Stages	Pressure ratio	Air mass flow			lb. th.	s.h.p.	e.h.p.	r.p.m.	lb./*/hr.	lb. th.	s.h.p.	r.p.m.	lb./*/hr.	in.	in.	in.	lb.	*/lb.wt.
	Tj.	Ax.	10	6.1 : 1	130.0	6	2	7,500	—	—	7,800	0.997	N.A.	—	N.A.	N.A.	N.A.	N.A.	42.0	2,470	3.04
	Tj.	Ax. + Ax.	N.A.	8.0 : 1	333.0	Ann.	N.A.	28,000*a*	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	231.0	42.0	4,300	5.0*a*
	Tj.	Ax.	7	3.8 : 1	55.0	Ann.	1	4,080*a*	—	—	11,800	1.07	N.A.	—	N.A.	N.A.	N.A.	78.8	28.75	750*b*	5.43*a*
	Tj.	Ax.	7	4.8 : 1	57.3	Ann.	1	4,450*a*	—	—	12,000	2.00*a*	N.A.	—	N.A.	N.A.	N.A.	146.0	26.0	850*b*	N.A.
	Tj.	Ax.	9	5.2 : 1	150.0	Ann.	2	9,700	—	—	8,400	0.98	8,300	—	8,300	N.A.	112.0	180.0	40.0	2,180*b*	5.45
	Tj.	Ax.	9	5.2 : 1	150.0	Ann.	2	13,250*a*	—	—	8,400	2.07*a*	11,800	—	8,400	N.A.	N.A.	263.8	42.0	2,755	4.80*a*
	Tj.	C.	1	3.95 : 1	7.05	Ann.	1	353	—	—	N.A.	1.17	287	—	N.A.	1.13	35.1	47.25	16.0	159	2.22
	Tj.	C.	1	3.85 : 1	17.64	Ann.	1	880	—	—	22,600	1.15	795	—	21,000	1.09	44.3	61.6	22.3	322	2.73
	Tj.	Ax. + C.	3	5.2 : 1	42.0	Ann.	1	3,395*a*	—	—	17,500	2.25	1,940	—	N.A.	0.96	N.A.	142.2*a*	26.5	970*a*	3.50*a*
	Tp.	Ax. + C.	2	N.A.	N.A.	Ann.	2×1	145.5	750	805	33,500	0.64	N.A.	N.A.	N.A.	N.A.	60.9	N.A.	21.6	467	1.72
	S.T.	Ax. + C.	2	5.1 : 1	10.60	Ann.	2×1	—	750	N.A.	34,500	0.77	N.A.	N.A.	N.A.	N.A.	65.5	N.A.	31.4	430	1.74
	S.T.	N.A.	N.A.	N.A.	N.A.	Ann.	N.A.	—	600	N.A.	N.A.	N.A.	—	500	N.A.	N.A.	N.A.	57.5	N.A.	317	0.89
	G.G.	C.	1	3.7 : 1	2.71	Ann.	2	—	—	252	34,000	1.23	—	231	N.A.	N.A.	41.8	48.5	19.7	198	1.27
	Tj.	Ax.	12	N.A.	110.0	Ann.	2	6,945	—	—	N.A.	0.85	N.A.	—	N.A.	N.A.	N.A.	161.4	38.6	N.A.	N.A.
	Tj.	C.	1	4.0 : 1	13.9	Ann. Rev.	1	716	—	—	25,000	1.18	N.A	—	N.A.	N.A.	N.A.	34.8	22.5	187	3.82
	Tj.	Ax.	9	5.5 : 1	110.0	Cann. 10	1	5,950	—	—	8,200	N.A.	N.A.	—	N.A.	N.A.	N.A.	100.78	42.12	1,080	5.51
	G.G.	C.	1	4.0 : 1	10.4	Ann.	1×1	—	—	542	25,000	N.A.	—	483*c*	24,000	1.28	48.4	N.A.	23.6	265	2.05
	Tj.	Ax.	8	N.A.	N.A.	Ann.	1	2,646	—	—	N.A.	N.A.	N.A.	—	N.A.	1.08	N.A.	72.85	28.35	815	3.25
	Tj.	Ax.	7	4.1 : 1	32.0	Ann.	1	1,750	—	—	13,800	1.12	1,475	—	13,100	1.10	46.58	66.98	24.3	530	3.44
	Tj.	Ax.	7	3.9 : 1	42.0	Ann.	1	2,460	—	—	13,400	1.11	2,020	—	12,700	1.10	47.77	69.17	24.3	535	4.60
	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	4,250	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	73.0	32.4	790	5.38
	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	5,000	—	—	N.A.	1.06	N.A.	—	N.A	N.A.	N.A.	75.45	32.4	825	6.06
	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	5,100	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	76.57	32.4	980	5.20
	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	4,230	—	—	N.A.	0.96	N.A.	—	N.A.	N.A.	N.A.	75.5	32.4	890	4.75
	Tj.	Ax.	8	N.A.	N.A.	N.A.	N.A.	6,810	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	82.7	32.4	1,100	6.19
	Tj.	Ax.	13	N.A.	N.A.	Ann.	2	12,300*a*	—	—	8,600	1.20*a*	9,600	—	8,200	0.845	107.7	130.7	37.4	3,180*a*	3.87*a*
	Tj.	Ax. + Ax.	5×6	N.A.	N.A.	Cann. 8	1×1	24,000*a*	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	126.4	41.75	3,600	6.67*a*
	Tp.	Ax.	11	5.85 : 1	2×21.0	Ann.	3	710	3,600	3,875	15,000	0.66	710	3,875*c*	15,000	0.66	84.62	103.35	56.55	2,560	1.55
	S.T.	Ax. + C.	2+1	5.9 : 1	12.5	Ann. Rev.	2×1	200	1,020	—	20,000*d*	0.71	182	930*c*	19,500*d*	0.72	48.53	60.0	27.4	550	1.85
	Tp.	Ax. + C.	2+1	5.9 : 1	12.5	Ann. Rev.	2×1	200	1,160	1,175	20,000*d*	0.65	180	1,030*c*	19,500*d*	0.65	42.3	59.97	27.4	600	1.96
	S.T.	C.	1	4.12 : 1	7.2	Ann.	1×1	N.A.	400	—	35,000	1.05	N.A.	350	34,000	1.07	45.6–56.2	N.A.	26.4	234–343	1.71–1.17
	S.T.	C.	1	4.12 : 1	7.2	Ann.	2	N.A.	475	—	35,000	0.99	N.A.	414	34,000	1.03	36.6–43.8	N.A.	19.25	255–315	1.63–1.51
	S.T.	Ax. + C.	2+1	6.35 : 1	11.0	Ann.	2×1	N.A.	840	N.A.	35,000	0.77	N.A.	700	N.A.	0.81	60.0	N.A.	20.0	390	2.15
	G.G.	C.	1	3.88 : 1	2.71	Ann.	2	—	—	252	35,000	1.23	—	231	35,000	1.24	33.5	N.A.	21.4	204	1.23
	Tp.	Ax. + C.	12+1	7.2 : 1	44.3	8	2×2	1,260	3,960	4,445	11,593	0.60	1,165	3,520	10,666	0.501	N.A.	100.6	40.1	2,900	1.53
	Tp.	Ax. + C.	12+1	7.2 : 1	N.A.	8	2×2	1,260	4,130	4,615	N.A.	N.A.	N.A.	N.A.	N.A.	0.484	N.A.	100.6	40.1	2,900	1.59
	Tj.	Ax.	8	7.0 : 1	150.0	Ann.	3	10,000	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	70.0	N.A.	32.3	2,000	5.0
	S.T.	Ax.	10	8.0 : 1	12.4	Ann.	2×1	—	1,000	—	19,500*e*	0.65	—	900	19,500*e*	0.67	54.8	N.A.	18.2	350*f*	2.86
	Tp.	Ax.	10	7.0 : 1	31.0	6	3	700	3,230	3,500	12,500	0.60	625	2,670	12,000	0.62	105.1	122.25	36.0	1,750	2.00
	S.T.	Ax.	11	6.37 : 1	17.5	6	2×1	340	1,800	—	20,400	0.66	285	1,200	18,800	0.74	70.0	N.A.	33.5	865	2.08
	Tj.	Ax.	12	6.4 : 1	124.0	8	2	8,000	—	—	8,100	0.93	N.A.	—	N.A.	N.A.	N.A.	102.1	42.2	2,520	3.17
	Tj.	Ax.	15	N.A.	N.A.	Cann. 8	2	11,250	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.	N.A.	117.5	42.0	N.A.	N.A.
	Tj.	Ax.	15	7.8 : 1	160.0	Cann. 8	2	10,000	—	—	8,000	0.86	N.A.	—	N.A.	N.A.	N.A.	113.3	41.5	2,890	3.46
	Tj.	Ax.	16	8.7 : 1	N.A.	Cann. 8	3	10,500‡	—	—	8,000	0.775	N.A.	—	N.A.	N.A.	N.A.	124.8	41.5	3,341	3.14
	Tj.	Ax.	7	N.A.	N.A.	Ann.	1	2,010	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	N.A.	N.A.	251	8.0
	B.P.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	12,000	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Tj.	Ax.	7	N.A.	N.A.	Ann.	1	2,750	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	N.A.	N.A.	344	8.0
	B.P.	Ax. + Ax.	N.A.	N.A.	N.A.	Cann.	N.A.	17,000	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	132.5	42.0	N.A.	N.A.
	B.P.	Ax. + Ax.	N.A.	N.A.	N.A.	Cann.	N.A.	18,500	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.	N.A.	132.5	42.0	N.A.	N.A.

Engine		
Make and name	Type	Type
UNITED KINGDOM—*Contd.*		
Dart R.Da. 3 Mk. 506	Tp.	C.
Dart R.Da. 6 Mk. 510	Tp.	C.
Dart R.Da.7/2 Mk. 526, 527 and 529	Tp.	C.
Dart R.Da.10 Mk. 540	Tp.	C.
Dart R.Da.11 Mk. 541	Tp.	C.
Tyne R.Ty.1 Mk. 505	Tp.	Ax. + Ax.
Tyne R.Ty.11	Tp.	Ax. + Ax.
Tyne R.Ty.12	Tp.	Ax. + Ax.
U.S.A.		
Allison		
J33–A–41	Tj.	C.
J71–A–11	Tj.	Ax.
Model 250–B2	Tp.	Ax. + C.
T56–A–1	Tp.	Ax.
Model 501–D13	Tp.	Ax.
Model 501–D15 (T56–A–7)	Tp.	Ax.
Boeing		
Model 502–10F	Tp.	C.
T60–2	Tp.	C.
Continental		
J69–T–19B (Turboméca Marboré)	Tj.	C.
Fairchild		
J44–R–26	Tj.	C./Ax.
General Electric		
J47–GE–33	Tj.	Ax.
J79–GE–1	Tj.	Ax.
CJ–805–3	Tj.	Ax.
CJ–805–21	Tf.	Ax.
J85	Tj.	Ax.
J93	Tj.	Ax.
T58–GE–6	S.T.	Ax.
Lycoming		
T53–L–1 (T53–L–3; Tp.)	S.T.	Ax. + C.
T55–L–1 (T55–L–3; S.T.)	Tp.	Ax. + C.
Pratt & Whitney		
JT12	Tj.	Ax.
JS7–P–19	Tj.	Ax. + Ax.
JS7–P–31 (JT3)	Tj.	Ax. + Ax.
JT3D–1	Tf.	Tf. + Ax.
J75–P–5	Tj.	Ax. + Ax.
JT4A–3	Tj.	Ax. + Ax.
J58	Tj.	Ax.
T34–P–3 and 7	Tp.	Ax.
T34–P–9W	Tp.	Ax.
Solar		
YT62 Titan (constant speed—YT66 variable speed)	S.T.	C.
Westinghouse		
J34–WE–46	Tj.	Ax.
J54–WE–2	Tj.	Ax.
J81 (dev. of R.R. Soar)	Tj.	Ax.
Wright		
J65–W–18 (A.S. Sapphire)	Tj.	Ax.
U.S.S.R.		
Klimov VK–1A (in MiG–17)	Tj.	C.
Mikulin RD–3 (in Tu–104, RD–3M in Tu–104A)	Tj.	Ax.
Mikulin M–209 (in Tu–16)	Tj.	Ax.
Kuznetsov NK–4 (in Il–18)	Tp.	Ax.
Ivchenko (in An–10)	Tp.	Ax.
Kuznetsov NK–012M (in Tu–114)	Tp.	Ax.
Soloviev TB–2–BM (in Mi–6)	S.T.	Ax.

Note.—Data in italics are estimated or un
turbine engine; Tf., turbofan; Tj., turbojet; Tp
c, e.h.p.; *d*, compressor r.p.m.; *e*, power turbine r.



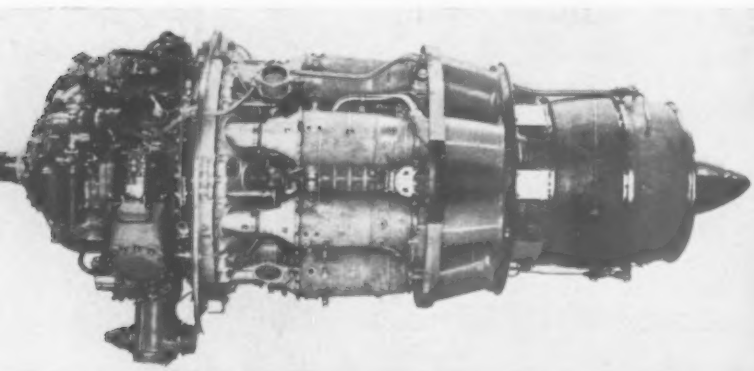


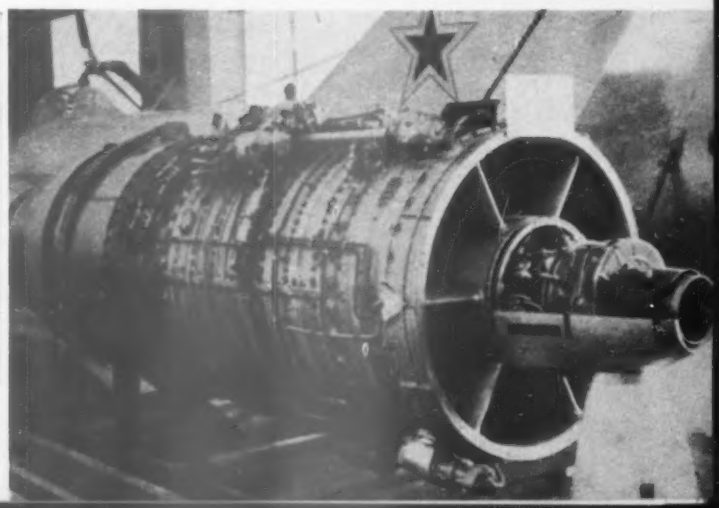
INTERNATIONAL ENGINES.—Left to right are the Pratt & Whitney J75 (U.S.A.), Rolls-Royce Dart R.Da.7 (U.K.), VEB Type 014 (German Democratic Republic), Bristol Proteus 765 (U.K.) and Mikulin RD-3 (U.S.S.R.).

ND FIGURES

Compressor				No. of combustion chambers	No. of turbine stages	Sea level static performance										Overall dimensions			Dry weight	Power/weight ratio
						Take-off					Maximum continuous					Length of engine	Length with ex. cone	Width or height		
Type	Stages	Pressure ratio	Air mass flow			lb. th	s.h.p.	e.h.p.	r.p.m.	lb./°/hr.	lb. th.	s.h.p.	r.p.m.	lb./°/hr.		in.	in.	in.	lb.	°/lb.wt.
C.	2	5.5 : 1	20.0	7	2	365	1,400	1,540	14,500	0.727	295	1,230c	13,800	0.79		95.0	N.A.	37.9	1,044	1.47
C.	2	5.5 : 1	20.0	7	2	370	1,600	1,740	14,500	0.69	320	1,400c	14,000	0.725		97.6	N.A.	37.9	1,152	1.57
C.	2	5.75 : 1	22.0	7	3	505	1,910	2,105	15,000	0.66	445	1,920c	14,400	0.745		97.6	N.A.	37.9	1,250	1.72
C.	2	6.35 : 1	25.5	7	3	670	2,440†	2,660	15,000	0.64	N.A.	N.A.	N.A.	N.A.		98.5	N.A.	37.9	1,323	2.01
C.	2	N.A.	N.A.	7	3	655	2,100	2,350	15,000	0.675	570	2,040c	15,000	0.70		98.5	N.A.	37.9	1,323	1.77
Ax. × Ax.	6×9	13.0 : 1	46.0	Cann. 10	1×3	N.A.	4,500	4,985	15,250	0.50	N.A.	N.A.	N.A.	0.405		100.25	N.A.	40.5	2,063	2.42
Ax. × Ax.	6×9	13.0 : 1	N.A.	Cann. 10	1×3	1,290	5,030	5,525	15,250	0.48	N.A.	N.A.	N.A.	0.388		100.25	N.A.	40.5	2,200	2.51
Ax. × Ax.	6×9	13.0 : 1	N.A.	Cann. 10	1×3	1,120	5,300	5,730	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		100.25	N.A.	40.5	2,200	2.61
C.	1	4.25 : 1	87.0	14	1	4,600	—	—	11,750	1.14	4,600	—	11,750	1.12		N.A.	159.5	49.4	1,790	2.57
Ax.	16	8.3 : 1	*160.0*	Cann. 10	3	10,200	—	—	6,100	0.80	N.A.	—	N.A.	N.A.		N.A.	191.0	47.6	4,090	2.49
Ax.+C.	7+1	N.A.	3.0	1 Flow	2×1	N.A.	250	N.A.	N.A.	0.70	N.A.	212	N.A.	0.73		38.5	N.A.	19.5	106	2.36
Ax.	14	9.25 : 1	32.5	Cann. 6	4	726	3,460	3,750	13,820	0.54	N.A.	3,375c	13,820	0.46		N.A.	145.1	40.0	1,645	2.28
Ax.	14	9.25 : 1	32.5	Cann. 6	4	726	3,460	3,750	13,820	0.54	702	3,094	13,820	0.555		N.A.	145.2	36.0	1,750	2.14
Ax.	14	9.25 : 1	39.0	Cann. 6	4	N.A.	N.A.	4,050	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	145.2	36.0	N.A.	N.A.
C.	1	N.A.	4.24	2	1×1	—	320	—	N.A.	0.92	—	N.A.	N.A.	N.A.		N.A.	41.5	24.25	300	1.07
C.	1	N.A.	5.5	2	1×1	—	400	N.A.	N.A.	0.72	—	350	N.A.	0.76		—	60.0	23.62	360	1.11
C.	1	4.0 : 1	16.7	Ann.	1	1,060	—	—	21,250	1.27	860	—	20,000	1.25		44.3	61.53	22.32	317	3.34
C./Ax.	1	3.25 : 1	N.A.	Ann.	1	1,100	—	—	N.A.	1.30	N.A.	—	N.A.	N.A.		N.A.	92.0	22.3	365*b*	3.02
Ax.	12	5.5 : 1	103.0	8	1	7,650*a*	—	—	7,950	2.00*a*	5,100	—	7,950	1.13		N.A.	228.0	36.75	3,196	2.40*a*
Ax.	17	12.0 : 1	162.0	Cann. 10	3	18,000*a*	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	204.0*a*	32.5	3,190	5.64*a*
Ax.	17	12.0 : 1	162.0	Cann. 10	3	11,200	—	—	N.A.	0.8	N.A.	—	N.A.	N.A.		N.A.	110.3	31.6	2,780	4.03
Ax.	17	12.0 : 1	N.A.	Cann. 10	3+Tf.	15,100	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	144.0	53.0	3,700	4.07
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	2,450	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	N.A.	N.A.	300	8.16
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.
Ax.	10	Over 8.0 : 1	12.4	Ann.	2×1	—	1,050	—	19,500e	0.67	—	900	—	N.A.		55.0	N.A.	27.3	342*f*	3.07
Ax.+C.	5+1	6.0 : 1	10.7	Ann. Rev.	1×1	102	825	866	25,240	0.673	96	770	N.A.	0.689		47.61	N.A.	23.0	480*b*	1.80
Ax.+C.	7+1	6.2 : 1	20.0	Ann. Rev.	2×1	190	1,600	1,676	18,100	0.648	168	1,325	N.A.	0.685		58.85	N.A.	24.25	695	2.41
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	3,000	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	N.A.	N.A.	430	6.97
Ax. × Ax.	9×7	12.5 : 1	180.0	Cann. 8	1×2	12,100	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.		N.A.	157.52	40.5	3,970	3.05
Ax. × Ax.	9×7	12.5 : 1	180.0	Cann. 8	1×2	13,000	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.		N.A.	167.33	38.88	3,820	3.40
Tf. × Ax.	2× 6×7	N.A.	430.0	Cann. 8	1×3	16,000	—	—	8,200	N.A.	9,800	—	N.A.	0.755		148.0	180.0	53.0	4,400	3.64
Ax. × Ax.	N.A.	12.5 : 1	*260.0*	Ann.	N.A.	24,500*a*	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.		N.A.	259.3	43.0	5,950	4.12*a*
Ax. × Ax.	N.A.	12.5 : 1	260.0	Ann.	N.A.	16,800	—	—	8,000	N.A.	N.A.	—	N.A.	N.A.		N.A.	189.2	43.0	5,020	3.34
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	*30,000*	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.
Ax.	13	6.7 : 1	67.0	Ann.	3	1,250	5,500	6,000	11,000	0.63	1,125	4,750	5,200	0.655		N.A.	156.8	33.75	2,670	2.25
Ax.	13	6.7 : 1	67.0	Ann.	3	—	5,950	6,500	N.A.	0.60	N.A.	—	N.A.	N.A.		N.A.	154.1	33.75	2,870	2.27
C.	1	N.A.	N.A.	Ann.	1	12	55	N.A.	57,600	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	20.0	15.5	50	1.12
Ax.	11	4.35 : 1	N.A.	Ann.	2	3,400	—	—	12,500	N.A.	N.A.	—	N.A.	N.A.		N.A.	111.4	27.0	1,207	2.82
Ax.	16	8.0 : 1	100.0	Ann.	2	6,500	—	—	N.A.	0.85	N.A.	—	N.A.	N.A.		120.0	158.0	35.0	1,400	4.64
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	1,860	—	—	N.A.	1.27	N.A.	—	N.A.	N.A.		N.A.	58.9	15.8	275	6.76
Ax.	13	7.0 : 1	120.0	Ann.	2	10,500*a*	—	—	8,200	N.A.	N.A.	—	N.A.	N.A.		N.A.	182.0	37.5	3,425	3.07*a*
C.	1	4.5 : 1	N.A.	9	1	7,590*a*	—	—	13,000	N.A.	N.A.	—	N.A.	N.A.		N.A.	N.A.	50.3	*1,980*	*3.83*
Ax.	8	*6.8 : 1*	*278.0*	Ann.	2	14,850	—	—	N.A.	*0.90*	N.A.	—	N.A.	N.A.		N.A.	*200.0*	*54.0*	*5,500*	*2.7*
Ax.	*8*	N.A.	N.A.	Ann.	2	*18,040*	—	—	N.A.	N.A.	N.A.	—	N.A.	N.A.		N.A.	*200.0*	*54.0*	*5,500*	*3.3*
Ax.	*14*	*6.5 : 1*	N.A.	Ann.	3	N.A.	*4,000*	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.
Ax.	14	13.0 : 1	137.0	Cann.	5	2,645	12,000	N.A.	9,250	0.573	N.A.	N.A.	N.A.	N.A.		N.A.	236.2	45.3	5,070	2.37
Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	4,700	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.

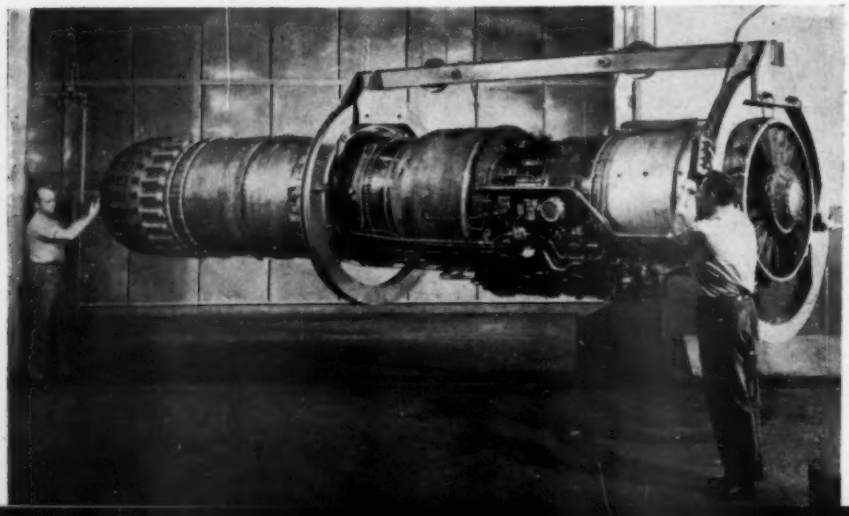
or unofficial. Abbreviations.—Ann., annular; Ax., axial; B.P., by-pass engine; C., centrifugal; Cann., cannular; G.G., gas generator; N.A., not available; S.T., shaft-et; Tp., turboprop; °lb. thrust, s.h.p., e.h.p. or g.h.p. as applicable to respective type of engine; † 3,200 mil. type test; *a*, with afterburner; *b*, less tailpipe; bine r.p.m.; *f*, with reduction gear; ‡ R.A.29/5, 13,300 lb.





Powerplant Survey . . . .

Engine		Compressor				No. of combustion chambers	No. of turbine stages	Sea le			
Make and name	Type	Type	Stages	Pressure ratio	Air mass flow			Take-off			
					lb./sec.			lb. th.	s.h.p.	e.h.p.	r.p
CANADA											
Orenda Engines											
Orenda Series 14	Tj.	Ax.	10	6.1 : 1	130.0	6	2	7,500	—	—	7,
Iroquois	Tj.	Ax. × Ax.	N.A.	*8.0 : 1*	*335.0*	Ann.	N.A.	*28,000a*	—	—	N.
FRANCE											
Marcel Dassault											
R.7 Farandole	Tj.	Ax.	7	3.8 : 1	55.0	Ann.	1	4,080a	—	—	11,
Hispano Suiza											
R.854	Tj.	Ax.	7	4.8 : 1	57.3	Ann.	1	4,450a	—	—	12,
Snecma											
Atar 8	Tj.	Ax.	9	5.2 : 1	150.0	Ann.	2	9,700	—	—	8,
Atar 9	Tj.	Ax.	9	5.2 : 1	150.0	Ann.	2	13,250a	—	—	8,
Turbomeca											
Palas I	Tj.	C.	1	3.95 : 1	7.05	Ann.	1	353	—	—	N.
Marboré II	Tj.	C.	1	3.85 : 1	17.64	Ann.	1	880	—	—	22,
Gabizo	Tj.	Ax. + C.	2	5.2 : 1	*42.0*	Ann.	1	3,395a	—	—	17,
Bastan	Tp.	Ax. + C.	2	N.A.	N.A.	Ann.	2×1	145.5	750	805	33,
Turmo III	S.T.	Ax. + C.	2	*5.1 : 1*	*10.60*	Ann.	2×1	—	750	N.A.	34,
Artouste III	S.T.	N.A.	N.A.	N.A.	N.A.	Ann.	N.A.	—	600	N.A.	N.
Palouste IV	G.G.	C.	1	3.7 : 1	2.71	Ann.	2	—	—	252	34,
GERMAN DEMOCRATIC REPUBLIC											
Type 014	Tj.	Ax.	12	N.A.	110.0	Ann.	2	6,945	—	—	N
ITALY											
Fiat											
Type 4002	Tj.	C.	1	4.0 : 1	13.9	Ann. Rev.	1	716	—	—	25
Type 4032	Tj.	Ax.	9	5.5 : 1	110.0	Cann. 10	1	5,950	—	—	8
Type 4700	G.G.	C.	1	4.0 : 1	10.4	Ann.	1×1	—	—	542	25
JAPAN											
Nippon Jet-Engine Co.											
Model J3-1	Tj.	Ax.	8	N.A.	N.A.	Ann.	1	2,646	—	—	N
UNITED KINGDOM											
Bristol-Siddeley Engines											
Viper Mk. 102 A.S.V.8	Tj.	Ax.	7	4.1 : 1	32.0	Ann.	1	1,750	—	—	13
Viper A.S.V.11	Tj.	Ax.	7	3.9 : 1	42.0	Ann.	1	2,460	—	—	13
Orpheus 701 B.Or.2	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	4,250	—	—	N
Orpheus 801 B.Or.3	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	5,000	—	—	N
Orpheus 810 B.Or.3/5	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	5,100	—	—	N
Orpheus B.Or.4	Tj.	Ax.	7	N.A.	N.A.	Cann. 7	1	4,230	—	—	N
Orpheus B.Or.12	Tj.	Ax.	8	N.A.	N.A.	N.A.	N.A.	6,810	—	—	N
Sapphire A.S.Sa.7R	Tj.	Ax.	13	N.A.	N.A.	Ann.	2	12,300a	—	—	8
Olympus Mk. 201 B.Ol.7R	Tj.	Ax. × Ax.	5×6	N.A.	N.A.	Cann. 8	1×1	24,000a	—	—	N
Double Mamba A.S.M.D.8	Tp.	Ax.	11	5.85 : 1	2×21.0	Ann.	3	710	3,600	3,875	15
P.181 (helicopter)	S.T.	Ax. + C.	2+1	5.9 : 1	12.5	Ann. Rev.	2×1	200	1,020	—	20
P.182 (fixed-wing)	Tp.	Ax. + C.	2+1	5.9 : 1	12.5	Ann. Rev.	2×1	200	1,100	1,175	20
Blackburn											
Turmo 600	S.T.	C.	1	4.12 : 1	7.2	Ann.	1×1	N.A.	400	—	35
Artouste 600 Bn.A.1	S.T.	C.	1	4.12 : 1	7.2	Ann.	2	N.A.	475	—	35
A 129	S.T.	Ax. + C.	2+1	6.35 : 1	11.0	Ann.	2×1	N.A.	840	N.A.	35
Palouste 500 Bn.Pe.1	G.G.	C.	1	3.88 : 1	2.71	Ann.	2	—	—	252	35
Proteus 765	Tp.	Ax. + C.	12+1	7.2 : 1	44.3	8	2×2	1,260	3,960	4,445	11
Proteus 770	Tp.	Ax. + C.	12+1	7.2 : 1	N.A.	8	2×2	1,260	4,130	4,615	N
de Havilland Engine Co.											
Gyron Junior D.G.J.10	Tj.	Ax.	8	*7.0 : 1*	*150.0*	Ann.	3	*10,000*	—	—	N
Gnome D.Ge.1	S.T.	Ax.	10	8.0 : 1	12.4	Ann.	2×1	—	1,000	—	19
D. Napier and Son											
Eland N.El.6	Tp.	Ax.	10	7.0 : 1	31.0	6	3	700	3,230	3,500	12
Gazelle N.Ga.3	S.T.	Ax.	11	6.37 : 1	17.5	6	2×1	340	1,800	—	20
Rolls-Royce											
Avon R.A.21	Tj.	Ax.	12	6.4 : 1	124.0	8	2	8,000	—	—	8
Avon R.A.24	Tj.	Ax.	15	N.A.	N.A.	Cann. 8	2	11,250	—	—	8
Avon R.A.28	Tj.	Ax.	15	*7.8 : 1*	*160.0*	Cann. 8	2	10,000	—	—	8
Avon R.A.29 Mk. 522, 524 and 525	Tj.	Ax.	16	*8.7 : 1*	N.A.	Cann. 8	3	10,500‡	—	—	8
R.B.108	Tj.	Ax.	7	N.A.	N.A.	*Ann.*	f	2,010	—	—	N
R.B.141	B.P.	Ax.	N.A.	N.A.	N.A.	N.A.	N.A.	12,000	—	—	N
R.B.145	Tj.	Ax.	7	N.A.	N.A.	*Ann.*	f	2,750	—	—	N
Conway R.Co.10 Mk. 505 and 507	B.P.	Ax. × Ax.	N.A.	N.A.	N.A.	Cann.	N.A.	17,000	—	—	N
Conway R.Co.15	B.P.	Ax. × Ax.	N.A.	N.A.	N.A.	Cann.	N.A.	18,500	—	—	N



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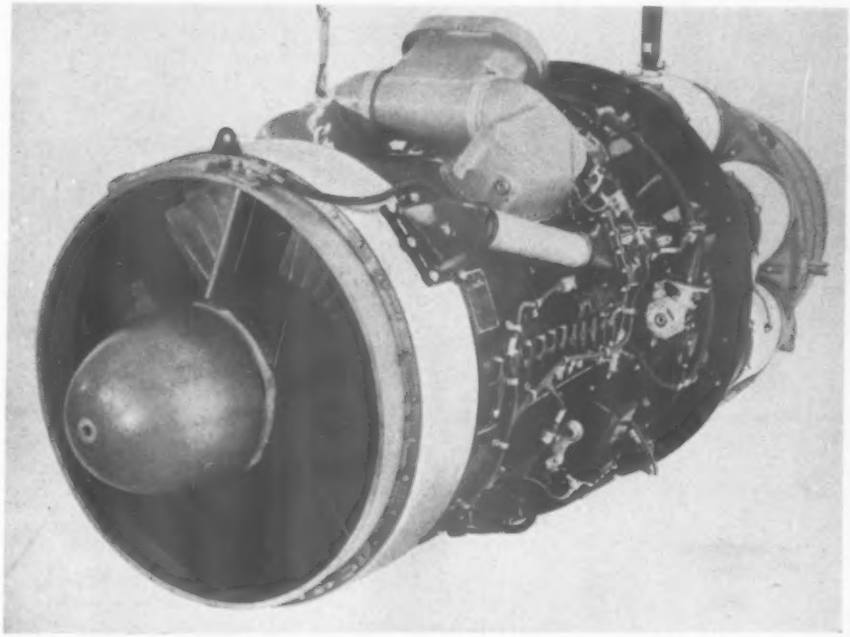


On early Rolls-Royce Avons there are three blow-off valves on each side for compressor matching; the ducting from them is prominent on top of the engine. Later Avons have slide valves instead of poppet valves.

(*Continued from page 152*)

they are so closely packed each is aerodynamically and mechanically coupled to many of the others.

When one blade row stalls, the effect on the compressor as a whole may well not be noticed, for the rest will shoulder the load and keep the engine going. In the process, the stalled blading is dragged through the air in a most inappropriate fashion. Since the stalled regions usually roll up into pockets, bands or cells distributed around the annulus and rotating at part engine speed, these blades are subjected to the same sort of treatment as an aircraft wing which is driven at 500 knots through alternate 200-knot upgusts and downgusts at 500-yard intervals.

Of course, the square-cube law helps, for no 12% thick aircraft wing could be made of solid steel. But since one broken blade can wreck an engine, and since the precise character, onset and mode of propagation of these stall cells are all virtually unpredictable, the only immediately possible step is evasion.

On the whole, a low pressure-ratio compressor properly matched should give no trouble, and so it was with the earliest axial engines. As the design pressure ratio is raised the contraction of the compressor annulus from inlet to outlet becomes more marked. At the design r.p.m. the compressor may deliver only one cu. ft. of air for each four or five aspirated, but during starting there is virtually no volume compression. As the rear end simply cannot pass four or five times its design volume flow the obvious happens and the front stages stall. At some intermediate r.p.m. the situation can sometimes be worse with the front stages stalled and the rear stages choked—Mach 1.0 in all the blade passages—for choking flutter also can break blades. Thus there exists a severe but thoroughly ill-defined physical limit to the design pressure ratio of a simple axial compressor cylinder.

The measures now adopted are of three types. The front stages of the compressor can be unstalled at low r.p.m. by turning in their sockets the inlet guide vanes alone, or the inlet guide vanes plus one or more rows of stator blading. This practice is now almost universal, but is particularly favoured by General Electric in America. Their T58-GE-2 of 10 stages and 8.3 : 1 pressure ratio has variable stagger on four blade rows and the J79-GE-1/3 of 17 stages and 12 : 1 pressure ratio on no less than seven.

The second device is an array of blow-off valves part way along the compressor, so that the back end volume flow can be reduced by opening these at low r.p.m. Needless to say, this scheme is used in conjunction with the first, the experts being Rolls-Royce with their Avon series in which the design pressure ratio has been raised no less than 50% in the process of stretch.

The third and most drastic move is the adoption of a double compound or two-spool layout as pioneered by Bristols in the Olympus. In a pure jet engine like this the two spools spin at much the same r.p.m. at the design point, but during starting the high-pressure rotor accepts the increased volume flow by running faster than the low-pressure one. With an optimum division of work the overall design pressure ratio should approach 15 : 1 before either compressor is as badly matched as the first, docile axials.

In the development of an engine many of these basic matching problems can of course be solved by isolated compressor testing before the final unit is run as a whole. The real trouble begins when the engine is flown for the first time under service conditions.

Compressor blade velocity triangles are such that a reduced volume flow is seen by the rotor as an "upgust" and an increased flow as a "downgust." Hence, given a poor inlet velocity profile, the blading will stall as it passes through that sector of the annulus where the velocity is lowest.

In a slight incident there may be a temporary formation of stall cells and the pilot will suspect nothing. In a major one the compressor will stall as a whole, in which event it is said to surge—a really violent mass instability of the whole column of air in the unit. Invariably there is a reversal of some if not all the air in the compressor, and there are pilots' tales of flames emerging from the intake!

Naturally, the combustion system is disturbed and in the worst conditions the flame is extinguished and the engine stops, or rather windmills—the effect commonly known as flameout. In certain military aircraft this has been known to happen in a sideslip, and it is always to be looked for in the manœuvring of a prototype machine at speed, especially in supersonic flight.

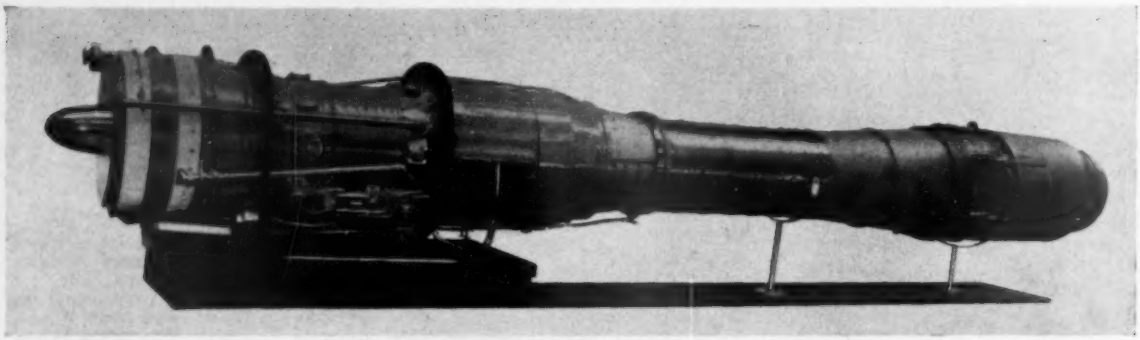
The same sort of trouble may be experienced when the intake is upset by gunfire, as in the early days of the Hunter, but here there is a double mechanism at work. Not only can the gun blast disturb the intake boundary layers and so ruin the inlet velocity profile, but when large volumes of gun gas (or exhaust gas from rocket weapons) enter the compressor there can also be a direct, volume flow type of effect.

A related trouble was the Britannia icing problem under freak tropical conditions. In the original installation ice could be collected in the intake by an unforeseen mechanism and then released in cakes. Mechanically, of course, the Proteus has the digestion of an ostrich, but when such a quantity of ice flashes into steam on its passage through a compressor there is a fair chance that something interesting will happen.

These, then, are the main physically limiting factors experienced to date, and enough has been said to show that

ERRATUM.—In the table alongside, two complete lines have been misplaced. The Proteus 765 and 770 are, of course, products of Bristol-Siddeley Engines and not of the Blackburn company as shown.

Powerplant Survey . . . .

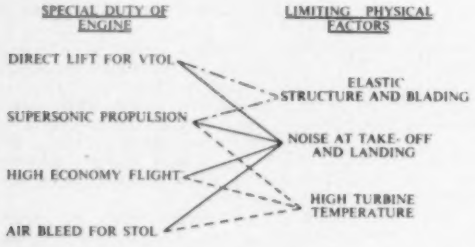


The two-spool layout was pioneered by Bristols in their Olympus turbojet as a means of raising design pressure ratio.

they fall into two classes—the frustrating but more or less clearly defined barriers imposed by the strength of materials and the properties of coolants and lubricants, etc., and the insidious aerodynamic diseases of the compressor. The latter may be fully understood some day, but for the present can strike in all sorts of unforeseen circumstances, however hard the design and development engineers have laboured.

POSSIBLE FUTURE PROBLEMS

Future problems will be decided by future requirements and in the absence of knowledge a broad view might suggest the following pattern:—



Elasticity

From the Hiller platform to the Gyron may seem a far cry, but for rather different reasons future supersonic and VTOL lifting engines seem likely to suffer from much the same elastic structural problems. In a VTOL aircraft the thrust will be 1.1 to 1.2 times the weight, and every ounce counts—so the engines, whatever their shape, must be of optimum size for minimum installed weight.

In a supersonic machine the engine weight should not be nearly so important, but a prodigious swallowing capacity will be required because, as the flight speed goes up, the thrust per lb./sec. of airflow comes down. Weight paring will be required to defeat the square-cube law on an overlarge engine.

In the early engines the structure weight was high on account of the lower limits to casting thickness and so on. After all, there was no need to go to great lengths when competing only with piston engines. As castings have given way to large forgings and latterly to fabrication from sheet metal, slashing reductions have been made, but never by cutting too near the bone. When this is done, as may well happen occasionally in the future, the engine structure will be much more easily excited by its rotor(s) or seriously flexed by gyroscopic loads.

In the limit, it is not too difficult to imagine an engine shaken apart by surging; and, of course, the rotating assemblies themselves will be more prone to whirling and gyro-elastic troubles. But the really troublesome thought is that none of these effects seems likely to be easily diagnosed or predicted. The position will be not unlike that now existing with the aerodynamic diseases of the compressor.

To stave off such ailments there is just one general move left; the length of the combustion system must be shortened. In the best modern practice the primary or reaction zone intensity is not substantially greater than that in the earliest engines. The doubling of the overall intensity has been wrought by reducing the volume of the subsequent dilution or mixing zone, partly by craft and partly by patient development. The last possible step is to remove this zone altogether and this is being done in the latest research chambers.

In the particular example shown, the fuel is distributed and atomized by a novel centrifugal element rotating with the main shaft. But once again the ultimate physical limits are so far removed that alternative burning arrangements will come to mind. The real advances are that the combustion engineer has at last settled the traditional argument about who owns the compressor outlet diffuser, and that he has contrived to eliminate his dilution zone by confining the mixing process to the nozzle guide-vane passages.

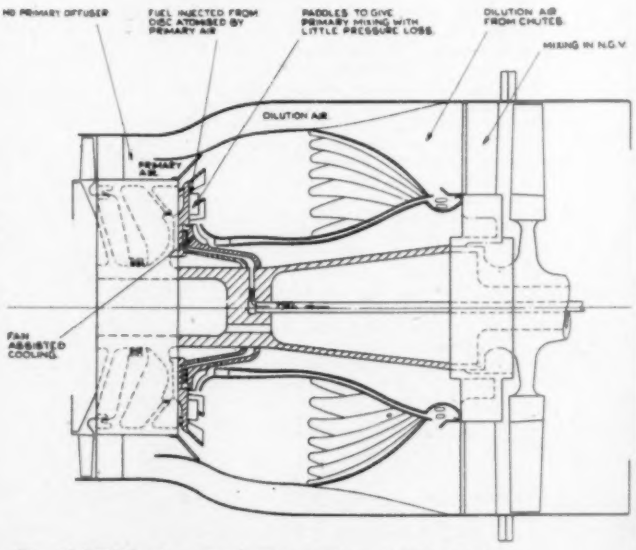
Specific to the direct-lift VTOL engine is the additional possibility of reinforced plastics compressor and fan blading. Before this can be realized, however, not only much development but a certain amount of fundamental research will be required.

Before the First World War it was known that the dynamic behaviour of a propeller blade at speed can be different from that when it is still, or rotating only slowly. The centrifugal field is the reason, but, because of the greater relative blade stiffness, the effects in a modern compressor are scarcely important, even at the highest tip speeds. But plastics have a much lower ratio of elasticity to density than metals and so could introduce major effects of this sort. It is too early to say, in this instance, whether or not a new physical barrier will be met: the effects could conceivably prove beneficial rather than harmful and only time will tell.

Temperature

In addition to making the use of plastics seem unlikely, the effects of high temperatures in supersonic and other

(*Continued on page 161*)


NO PRIMARY DIFFUSER
FUEL INJECTED FROM DISC ATOMISED BY PRIMARY AIR
PADDLES TO GIVE PRIMARY MIXING WITH LITTLE PRESSURE LOSS
DILUTION AIR FROM CHUTES
MIXING IN N.G.V.
DILUTION AIR
PRIMARY AIR
FAN ASSISTED COOLING

The N.G.T.E.'s short combustion system with an intensity of 6 x 10^6 C.H.U./hr./cu. ft./atm.

Adaptability

The GNOME
1000 S H P for 275 lb.

The de Havilland Engine Company Limited Leavesden, Hertfordshire.

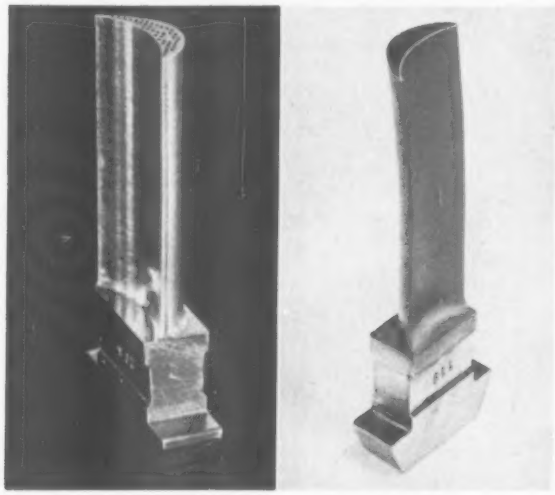
. . . and the AIR **BP** fuellers require a pressure of 100 lbs. per square inch at the pumps. But as the aircraft's system is designed for a maximum pressure of 50 lbs. per square inch, they are fitted with a highly sophisticated pressure control valve, and can safely fuel at 750 gallons per minute.

More than I could take on, old man.

AIR BP serves aviation well

THE AVIATION SERVICE OF BRITISH PETROLEUM

Powerplant Survey . . . .



Thermal stressing effects in an air-cooled blade from an early research turbine. On the left is the new blade; on the right the blade after 100 hours at top rating.

(*Continued from page 160*)

high-duty engines will introduce limits in other directions. As heat soaks down the discs to the bearings it must be removed and this is now done by the lubricating oil which, strictly speaking, is really only one per cent. a lubricant and 99% a coolant.

Because of the advance in synthetic oil technology, permissible bearing temperatures have risen about 100° C. since the early days, but unless some new chemical advance is forthcoming the end is in sight. Instead of using the actual lubricating spray to remove the heat, the next step is to divide the flow in two, most of the oil being pumped through heat throttles surrounding the vital components and the remainder only used for lubrication. After that there will be a requirement for special coolants and/or the ultimate step of refrigeration.

The high-pressure turbine is the hottest mechanical component, and before another decade has passed it is to be expected that blade cooling will be widespread if not universal. Cooling by the evaporation of water has been tried in full-scale research, but the most likely practicable arrangement is air cooling—as in, for example, the Avon R.A.29/5.

As it is not possible to produce cooling passages very near the thin trailing edges there are severe chordwise thermal gradients in blades of this sort. Hence the main problems are the distortion and weakening of the blades by thermal stressing and, to some extent, by thermal shock. Given adequate development and a heat sink, air-cooled blading for a large supersonic engine should be a relatively straightforward proposition, but in the high-pressure-ratio civil unit and especially in the turboprop engine, the small size of the blading could impose a limitation. Not only are smaller cooling passages more difficult to produce, but the reduced internal Reynolds number will mean a reduced rate of heat extraction.

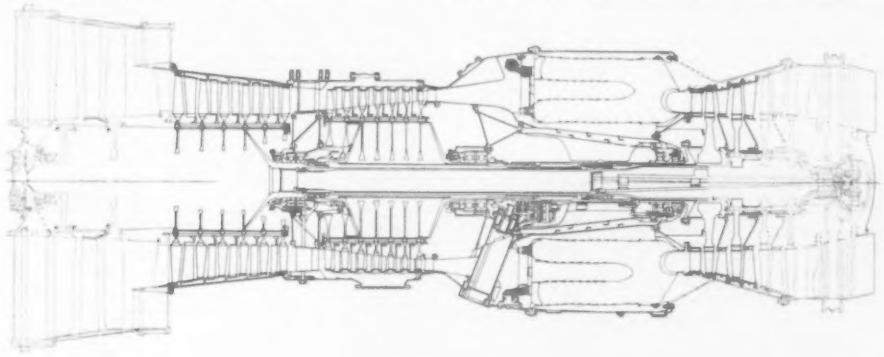
Noise and its Reduction

The present controversy concerning jet and propeller driven aircraft is no new thing; it has merely come to the surface. In the earliest days of the aircraft gas-turbine the projects and performance people wrangled no less earnestly than do the operators to-day; but also prominent in the picture there was the ducted fan or, as it was then sometimes called, the fan augmentor.

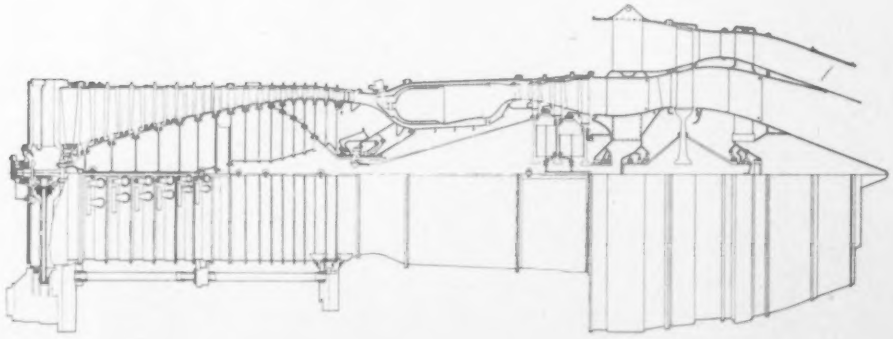
With the introduction of the by-pass engine and the military urge for supersonic flight, this seemed all but forgotten when General Electric and Pratt & Whitney last year disclosed their new commercial weapons. The reasons for the emergence of these particular turbofan engines—or rather jet engine conversion kits—at the present time are many and complex, but there is one specific reason why the breed might be expected to stay and multiply.

For a civil powerplant of the future, be it a turboprop, turbofan, by-pass or pure jet engine, economy and a spanking take-off thrust will not be enough. It will be the specific take-off thrust in lb. per watt, decibel, phon, sone, noy or whatever new unit is finally adopted, that will matter most. For the present, this choice of units is itself important; it reflects the true state of the art.

As is well known, the noise of a jet rises very rapidly with its velocity and is due to the process whereby it mixes with and

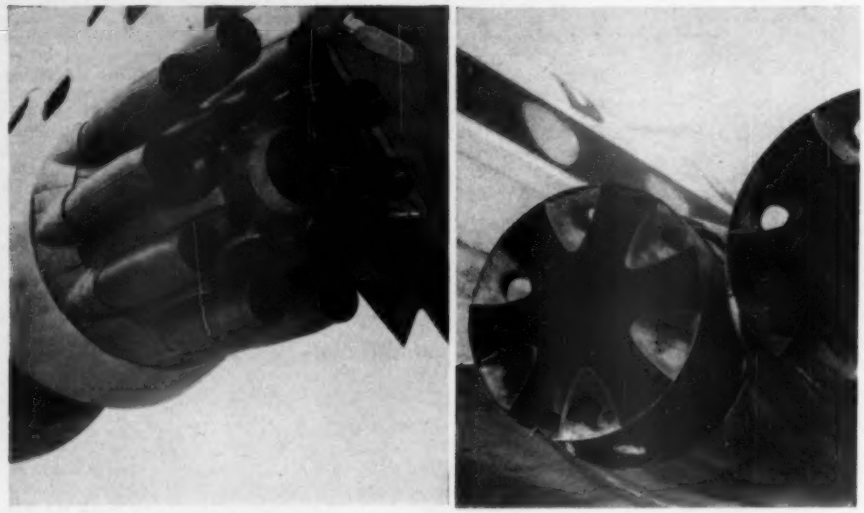


Left, the Pratt & Whitney JT3D-1 turbofan engine.



Right, the General Electric CJ-805-21 turbofan engine.

Powerplant Survey . . . .



Present jet "silencing" techniques. Left, Boeing 707 and right, de Havilland Comet 4.

is dissipated in the surrounding atmosphere. Because, in terms of nozzle diameters, much of this process takes place a long way downstream of the nozzle, the gains possible with the present techniques of "silencing" are relatively trivial. They permit existing engines to get by under strictly controlled conditions, but only just; the real answer is to reduce the jet speed substantially.

However, in listening carefully to the noise of most modern jet aircraft at take-off it can be discerned that the noise from the engine proper is only just masked by that of the jet. Reduce the latter and the engine noise will obtrude, as it does now, with a turboprop aircraft.

This engine noise is of two sorts. There is a random, or white, noise which is closely allied to the jet noise in both character and origin. This component is generated by the shed vorticity and turbulence in the turbo-machinery, and so it is called vortex noise. If the blading were to operate with potential flow this noise would be non-existent; as it is, it appears to be independent of all the usual variables such as Mach number, linear scale, C_L and so on, and to vary only with horse-power.

Because, as with the jet noise, there seems little that can be done to prevent each horse-power producing its quota, the main hope lies in preventing or reducing the escape of the noise from the engine. Hence the greatest difficulty is to be envisaged with direct-lifting VTOL engines, where the intake and exhaust systems must be vestigial.

The other sort of engine noise is the combination of tones produced by the passage of the blading; tones which would be produced in principle even in potential flow. If a compressor rotates with a peripheral velocity of 4,000 first-stage rotor blade pitches per second, a note of 4,000 c.p.s. will be heard. If all is well the harmonics will not obtrude, but if the Mach number is too high or the stage in question is stalled, there may be as much sound energy released at 8,000 c.p.s. and 12,000 c.p.s. as at 4,000. And this goes for every stage in the engine.

Whilst not carrying the same total energy as the vortex noise (by an order of magnitude or so) this ordered noise can be physiologically and psychologically more distressing and so may require a disproportionate amount of attention. With either of the two new turbofan units, or with such correspondingly high by-pass ratio engines as might be developed from the Conway layout, the ordered noise problem may well result in the designer being squeezed between a converging pair of different physical limitations. If the fan or low-pressure compressor tip speed be raised, there may be too much noise; if it be lowered, the fan turbine or low-pressure turbine will be overloaded so that its efficiency is reduced. Add the fact that in the General Electric engine the fan blades are actually carried by the turbine and one has a situation which calls for really nice judgment.

Whatever his product, the aircraft gas turbine engine man will clearly be well exercised and sorely tried for a long time to come.

Current British ramjet developments are represented by the Bristol Thor —seen here on test. It burns kerosene and delivers a thrust in the region of 20,000 lb. The length of the Thor unit is 94.5 in. and its diameter is 15.75 in.

Powerplant Survey . . . .

Rocket Engine Developments

by Dennis S. Carton, A.F.R.Ae.S., M.A.R.S., F.B.I.S.†

IN recent years, the changes of emphasis and the needs of security have hidden much of the continuity of improvement that has taken place in the rocket engine field. Here an attempt is made to review the trends to date—and to discuss the way in which improvements in performance and reliability have been brought about in both solid and liquid propellent engines—before taking a look into the future.

In the early days of rocket engines, in general, factors other than pure performance considerably affected the selection of propellents. The problems of heat transfer and stressing resulted in the general usage of propellent giving temperatures of 2,000-2,500° K. for liquids and often lower with solids and ideal exhaust velocities less than 5,000 ft./sec. In liquids, propellents were used that could carry water in order to lower combustion temperature and also improve the propellent as a coolant.

Combustion-chamber volumes tended to be large and resulted in large coolant temperature rises. Examples of these types of propellent are: fuels—alcohol, hydrazine hydrate; oxidants—nitric acid, hydrogen peroxide. Solid propellent compositions that carried considerable quantities of excess fuel were usually selected. Better propellents, at no increase in cost, were known—but not generally used because of the engineering problems involved.

So far as can be seen, the trend up to the present time has resulted largely from improvement of knowledge both in the combustion field and in engineering techniques, and also from the availability of improved materials. On the liquid propellent side, oxygen and kerosene have now almost completely superseded oxygen/alcohol systems in the first-stage engines of the largest present-day vehicles. Combustion pressures have been raised from 200-300 p.s.i. up to 500-600 p.s.i. Combustion chamber volumes have been reduced and the ratio L* (=combustion chamber volume/nozzle throat area) reduced from more than 100 in. to probably half this figure.

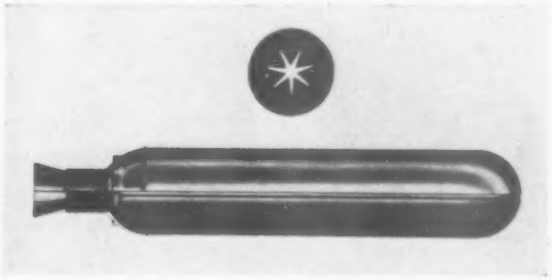


Fig. 1. A cross-section of a typical Thiokol solid-propellent rocket engine of the "cast-in-place," internal burning type.

Below right, developed from the variable-thrust Spectre hydrogen peroxide/kerosene rocket engine, the de Havilland Spectre D.Spe. 4 is a fixed-thrust A.T.O. unit for V-bombers.

Aircraft rocket engines have not followed the same trend; as performance in this case is subservient to problems of safety, long life and the aircraft's military or scientific applications. In this country the present-day emphasis is on hydrogen peroxide/kerosene, as used in the de Havilland Super Sprite and Spectre and the Napier Scorpion.

The work of Armstrong Siddeley on the early oxygen/kerosene Screamer engine was unfortunately dropped because of the success of hydrogen peroxide and the problems involved with use of liquid oxygen in tactical aircraft. France surprisingly continues to use nitric acid for military aircraft application. The United States uses liquid oxygen both for research aircraft and for military manned aircraft.

Improvements that have occurred on the solid propellent side of the picture are due as much to the chemist as to the engineer. That these improvements have been considerable is strongly underlined by the completely general move that has been made away from liquids in all applications—except for the very largest vehicles and piloted aircraft.

This indicates that many of the problems of early solid propellents have been overcome. For example, accurate reproducability and control of burning rate from several inches a second right down to less than 1/100th of this would appear to have been obtained. There is a better appreciation, too, of the effects of "errosive burning" (which is an increase in burning rate associated with high surface gas velocities); of temperature sensitivity (the effect on burning rate of propellent temperature immediately before ignition); and of pressure sensitivity (the effect on burning rate of combustion pressure). Also, the problem of detonation or explosion sensitivity must have been considerably improved.

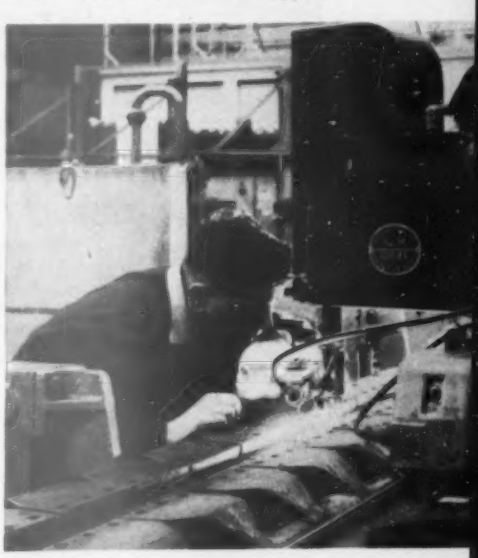
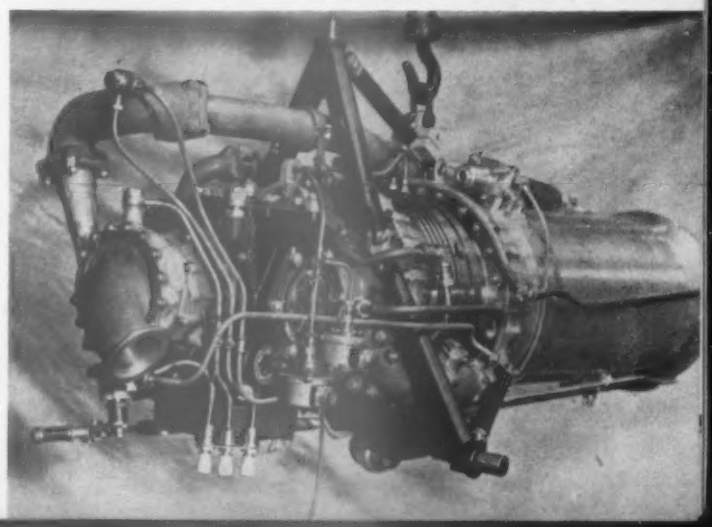


Fig. 2. Welding up the longitudinal seam in a Bristol rocket motor case. Argon arc welding is extensively used in this work.

It is most difficult to be as explicit about solid propellent performance as with liquids. Most solids contain two or three main ingredients with a number of additives included to control such characteristics as burning rate and physical characteristics. Performance, burning rate and combustion temperature do not change in an orderly manner with quantity of a single additive. The possible number of combinations, therefore, is extremely large.

In this country and the United States there are a large number of solid propellent applications worthy of note—small boost



† Lecturer in the Department of Aircraft Propulsion at the College of Aeronautics.

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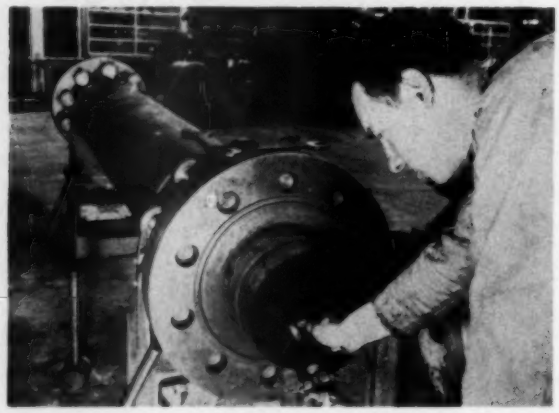


Fig. 3. In order to obtain the close limits necessary for a solid rocket case, a stretch-forming operation is used.

units 4-5 in. in diameter and 3-4 ft. in length with burning times of only a few seconds. Aircraft booster units, such as the Aerojet-General 1,000-lb.-thrust/15-second engine, are now receiving a United States grooming for civil applications with an "off-the-shelf" cost quoted as $155. (At 1 cent per lb. second of impulse there should be a wide range of possible applications.)

In this country the largest unclassified solid rocket motor is the Raven unit, used to power the British I.G.Y. vehicle Skylark. This is 17 in. in diameter and 15 ft. long with a thrust of about 10,000 lb. available for 30 seconds. The propellent in this application is a plastic composition containing ammonium perchlorate, ammonium picrate and a polymeric hydrocarbon acting as fuel and binder. The effective exhaust velocity obtained from this mixture is 5,700 ft./sec.—which low value is probably due to the need to limit gas temperature and to restrict the burning rate to a low figure.

The largest known solid propellent rocket has a case of 4 ft. 6 in. diameter and 9 ft. length. This American unit is thought to be in use as the first-stage power supply for the Polaris underwater-to-air missile for the U.S. Navy.

There is a fundamental difference between the variation of mass with size for solid and liquid propellent engines. With the former types of engine, the pressure casing contains the entire propellent. The most important parameters determining the mass of the engine (exclusive of its propellent) are, therefore, the total impulse (thrust and burning time), the effective exhaust velocity and the loading density (the proportion of chamber volume which actually contains propellent).

With a liquid propellent engine, on the other hand, the size of most of its components are related to the propellent or gas, mass-flow rate. The most important parameters determining the mass of the engine are thrust and effective exhaust velocity.

In vehicles having a pumped engine propellent supply, tanks are of very light construction. Their mass is small compared with solid propellent engine cases of similar proportions. Only in designs using highly pressurized liquid propellent systems is there any scaling similarity with the solid units.

With solid propellent rocket-motor cases, material requirements are to a large extent dependent upon the manner in which the propellent burns. With propellent shapes involving end burning, external burning, or the equalization of pressure at the external surface, the case material will suffer a considerable loss in strength as a result of heating. Only if the propellent burns from a central hole outwards, and the external surface is adequately bonded to the casing, is it possible to use material strength at comparatively low temperatures (see Fig. 1).

Fig. 4. After heat treatment the low alloy steel cases have a breaking stress of 80 tons/sq. in.; they are designed to withstand internal pressures of more than 2,000 p.s.i.

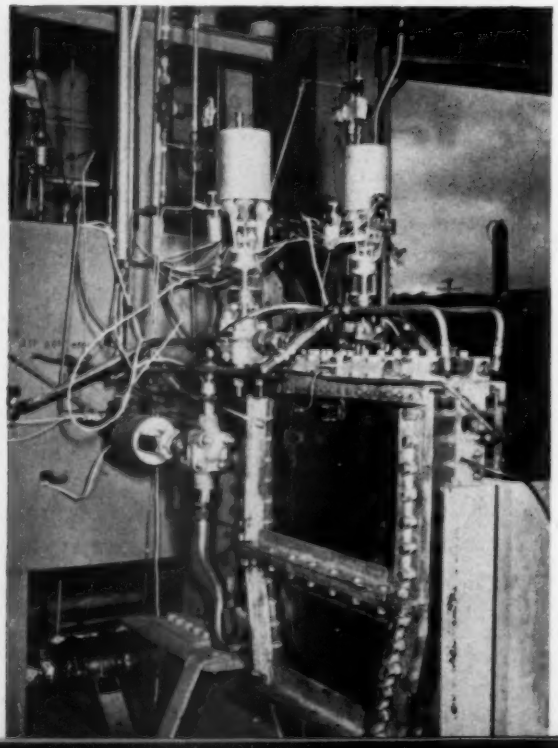
A great deal of study has been undertaken in the field of metallurgy to improve quality, and quality control, to permit the construction of cases that are both lighter and more reliable than was possible only a few years ago. It is now possible to obtain alloy steel sheet, suitable for manipulation into cases, having a yield strength better than 100 tons/sq. in. with remarkable control on thickness and quality.

Most cases are made up from sheet material rather than tube because of better control on thickness, ovality and bow. Special welding and heat-treatment techniques are needed.

In this country one manufacturing centre is the Bristol factory at Banwell. It is here that the cases for a large number of boost and sustainer units—including Raven—are made (see Figs. 2-4). These cases have to meet stringent requirements and their development and manufacture are undertaken in conjunction with the Rocket Propulsion Establishment at Westcott.

Materials other than high-grade steel have also been found suitable for rocket cases. One particularly interesting development is the utilization of glass-fibre reinforced epoxy resin. Quite an extensive programme has resulted in a demonstration tube with a diameter of 60 in.

A self-destroying booster has been produced in glass fibre—a



This full-scale "slice" research engine is used by Rocketdyne for two-dimensional combustion research.

Fig. 5. A cooled combustion chamber made up of aluminium tubes, developed by the General Electric Company in America.

charge blowing it into small pieces after separation. This is utilized on the Nike-Hercules surface-to-air anti-aircraft missile which is intended for operation over populous areas. It is claimed that 20% reduction in mass is obtained by using glass laminate.

In liquid propellent engines, a great deal of improved understanding of operating conditions has resulted in both a decrease of mass and an increase in reliability. External to the combustion chamber, problems of material compatibility with reactive or low-temperature liquids are constantly met. The design of on/off valves, flow controls, pumps, etc., of increasingly large size and accuracy of operation have involved many problems of sealing and heat control.

In the case of the lower-thrust engines, such as those used in piloted aircraft, most combustion chambers are of alloy or stainless steel. Manufacture is usually by forging and subsequent machining, resulting in the required control of quality and dimensions.

Quite recently, however, a new technique has been developed for the construction of chambers to give thrusts of 20,000 lb. and above, which is rapidly gaining favour. The wall of the chamber is made of a number of suitably shaped metal tubes, running from injector to nozzle exit, through which coolant flows. Gas leakage is prevented by soldering, brazing or welding the tube contacts together. Complete gas loads are carried by a number of clamping rings around the outside circumference at various points.

The General Electric Company in America have produced such a unit using aluminium tubes (see Fig. 5).

Rocketdyne, who produce the powerplant for the Jupiter, Thor and Atlas ballistic missiles, use for these engines nickel tubes with an inside diameter of 0.045 in. Three hundred of these tubes are changed to rectangular form and contoured to chamber shape by press and hydraulic forming. Held in place by an internal jig and external stress bands, they receive a brazing/welding treatment to complete the operation. Obviously this tube technique considerably helps the cooling problem without involving much mass change.

In addition to the combustion chamber, the injector has also received its share of improvement. This piece of equipment probably requires the closest control of all the rocket engine's components. A large number of holes of small size are needed with close tolerances on position and alignment, and on material finish at entrance, exit and bore. Fig. 6 shows an injector for engines of 20,000 lb. thrust which has a surface area per lb. of thrust less than one-quarter of that of the V2 unit.

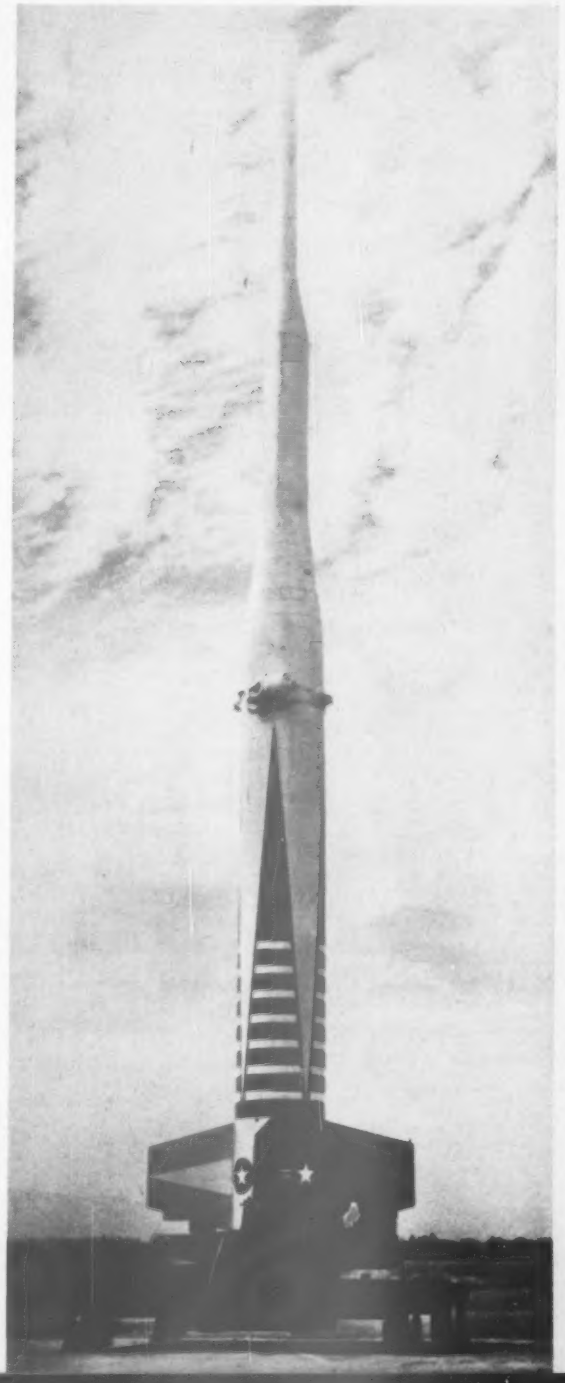
Nozzle construction depends on whether cooling is available or not, on the firing time, and on gas temperatures. With most cooled engines the nozzle is integral with the combustion chamber. Uncooled nozzles may be of metal, ceramic or of asbestos/resin construction. Durestos (a phenolic resin-impregnated asbestos) is used in this country to provide thermal insulation of the internal surface of some engines, as a transfer tube from combustion chamber to nozzles, and in the expansion section itself. The Raven, for example, has such an expansion cone.

Nozzles have been designed with walls curved in the axial plane. Known as " tulip " nozzles, their function is to decrease the non-axial velocity component at exit thus raising the thrust for a given application. Such nozzles are used in the Rocketdyne engines.

Present Developments and the Future

With the ever-increasing size of vehicles being used to place larger and larger payloads farther and farther away from the Earth, a number of problems arise. One of these is the question of how far solid propellent engines will continue in the present trend of taking over continuously growing areas of application.

So far as propellent performance is concerned, there are possible liquids capable of ideal exhaust velocities 15%-20% greater than is possible with any known solids. But the problem



An example of a multi-stage solid rocket system is the Lockheed X-17 re-entry test vehicle which has five Thiokol rocket engines.

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is very much more involved than this. Final selection must include consideration of material costs and the price of research and development of the propellent, and also of the development of power unit and vehicles to a given or acceptable standard of reliability.

Closely allied to this is an unresolved question of whether one engine or a group should be used. Whilst it takes longer to bring a cluster of engines to the same level of reliability as a single unit, much of the development of a cluster can be done on one chamber at reduced cost.

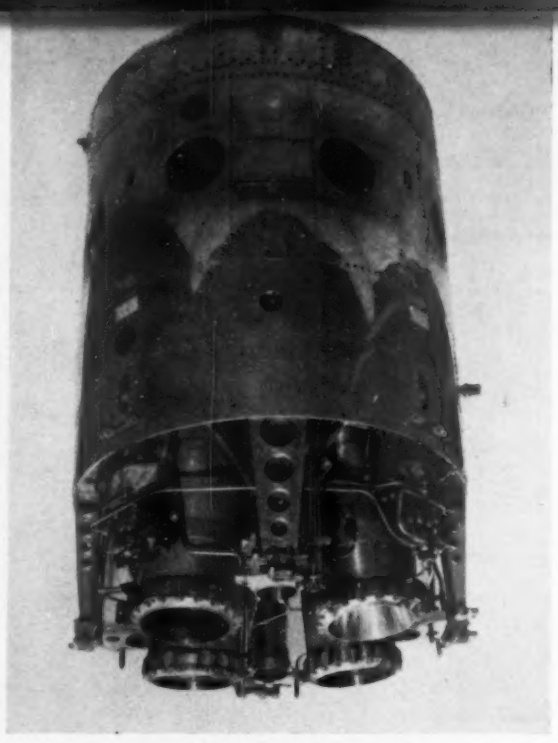
The question of safety with possible manned applications is also involved. The failure of one engine in a cluster may cause a mission failure, but may not be fatal. The survival procedure for the one-engine case must be extremely rapid.

One of the difficulties with the large engine is the fact that it is not possible to scale up either from a smaller successful engine or from smaller-scale research. All the development must be carried out at full scale; and this will probably remain true for a long time.

The main difficulty involved in scaling is the ever-present possibility of high-frequency combustion instability occurring. No guaranteed methods by which this can be cured quickly are as yet known.

An interesting development in the liquid propellent field is the production of a "packaged engine" complete with tanks already filled with propellents. Such storable engines probably use either an inhibited nitric acid or N_2O_4 (dinitrogen tetra oxide) as an oxidant. These have a number of advantages over known solids. They have good performance and are not particularly sensitive to environmental changes in, say, temperature and humidity.

The system is a very simple pressurized tank arrangement with a single explosive valve operation. It is thought that there may be a considerable application for such systems in both air-to-air and ground-to-air tactical guided weapons.



Powerplant for the Saunders-Roe Black Knight re-entry test vehicle, the Bristol-Siddeley Gamma Mk. 201 rocket engine, is based on the single-barrel Gamma developed by the Rocket Propulsion Establishment at Westcott. It has a sea-level thrust of 16,400 lb., rising to 19,000 lb. outside the Earth's atmosphere. Kerosene fuel and H.T.P. oxidant are used.

Fig. 6. This combustion chamber injector for a 20,000 lb. s.t. liquid-propellent engine has been developed by General Electric.

Future trends, nevertheless, are hazed by a number of possibilities, the importance of which can only be guessed at. Continuously improved research may solve combustion instability. The rate of improvement of usable (as opposed to paper-study "use") propellents may be influenced by the use of boron compounds, metal additives, and even by the stabilization of some chemical radicals or atoms.

Once out in space, chemical propulsion will most probably be uneconomical, and in this case a number of possible propulsion methods are available that may prove to be better. The use of an atomic pile to heat a gas or the applications of electro-magnetic forces to produce an ion discharge are two such possibilities.

The only certainty is that improvements and discoveries will take place in recognized techniques and possibly in completely new fields. One can hope that, in time, the new knowledge will trickle down to commerce and into our daily lives.

Engine		Duty	No. of comb. chamb.	Propellents			Thrust	Propellent supply means	Normal firing time	Overall dimensions		Dry weight
Make and name	Type			Oxidant	Fuel	Coolant				Length	Width	
							lb.		sec.	in.	in.	lb.
FRANCE												
S.E.P.R. 841	L.P.R.	A.F.	1	Nitric acid	Furaline	N.A.	3,700	N.A.	A.T.	N.A.	N.A.	190
2020	L.P.R.	M.P.	1	Nitric acid	Furaline	N.A.	2,975	N.A.	31	146.5	26.4	955
5052	S.P.R.	M.P.	1	—	N.A.	—	29,760	—	4	107.6	18.3	1,032
50531	S.P.R.	M.P.	1	—	N.A.	—	17,200	—	4	76.3	18.3	714
681	S.P.R.	M.P.	1	—	N.A.	—	22,050	—	8	77.2	9.3	186
732	S.P.R.	M.P.	1	—	N.A.	—	44,100	—	4.5	109.4	25.08	1,682
SWEDEN												
Svenska Flygmotor VR3	L.P.R.	A.F.	1	H.T.P.	Kerosene	H.T.P.	5,700	N.A.	A.T.	39.4	11.8	165
UNITED KINGDOM												
Bristol-Siddeley Engines												
PR.23	L.P.R.	M.T.	1	H.T.P.	Kerosene	—	500	—	A.T.	N.A.	N.A.	30.32
Gamma Mk. 201	L.P.R.	M.P.	4	H.T.P.	Kerosene	H.T.P.	19,000	Turbo-pumps	A.T.	N.A.	N.A.	700.0
Raven	S.P.R.	M.P.	1	—	N.A.	—	11,500	—	30	216	N.A.	N.A.
de Havilland												
Spectre D.Spe.5	L.P.R.	A.F.	1	H.T.P.	Kerosene	H.T.P.	*8,000*	Turbo-pumps	A.T.	56.5	26.5	N.A.
Spectre D.Spe.4	L.P.R.	A.T.O.	1	H.T.P.	Kerosene	H.T.P.	*8,000*	Turbo-pumps	N.A.	59.2	21.5	N.A.
Double Spectre D.Spe.D.1	L.P.R.	A.F./M.P.	2	H.T.P.	Kerosene	H.T.P.	*16,000*	Turbo-pumps	A.T.	58.6	36.6	N.A.
Rolls-Royce												
All current rockets secret												
U.S.A.												
Aerojet-General												
All current rockets secret												
Thiokol Reaction Motors												
LR8–RM–6	L.P.R.	A.F.	4	Liquid oxygen	Ethyl/alcohol/water	Fuel	6,000	Press-tanks	A.T.	56.0	19.0	210
XLR99–RM–2 Pioneer	L.P.R.	A.F.	1	Liquid oxygen	Ammonia	N.A.	60,000	Turbo-pumps	A.T.	N.A.	N.A.	N.A.
LR44–RM–2 Guardian	L.P.R.	M.P.	1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Patriot	L.P.R.	M.P.	1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TU 205	L.P.R.	M.P.	2	N.A.	N.A.	N.A.	200	N.A.	N.A.	N.A.	N.A.	N.A.
Rocketdyne												
A–6	L.P.R.	M.P.	1	Liquid oxygen	Alcohol	N.A.	75,000	Turbo-pumps	A.T.	N.A.	N.A.	1,450
S–3 (LR79–NA–1)	L.P.R.	M.P.	1	Liquid oxygen	RP–1	N.A.	150,000	Turbo-pumps	A.T.	N.A.	N.A.	N.A.
LR93–NA–1	L.P.R.	M.P.	1	Liquid oxygen	RP–1	N.A.	165,000	Turbo-pumps	A.T.	N.A.	N.A.	N.A.
LR105–NA–1	L.P.R.	M.P.	1	Liquid oxygen	RP–1	N.A.	60,000	Turbo-pumps	A.T.	N.A.	N.A.	N.A.

Abbreviations: A.F., Aircraft flight rocket engine; A.T., according to aircraft tank capacity; A.T.O., assisted take-off unit; H.T.P., high-test hydrogen peroxide; L.P.R., liquid-propellent rocket; M.P., missile powerplant; M.T., missile trimmer engine; N.A., not available; S.P.R., solid-propellent rocket. Data in italics are estimated.

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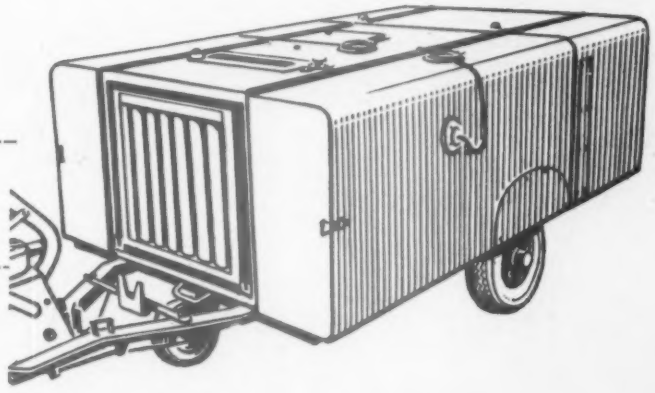

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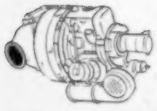

The P.181 for helicopters is Armstrong Siddeley's latest contribution to civil aviation.
This 1,000 h.p. gas turbine has a low installed weight and is mechanically simple.
It has safety features built into the basic design and meets all fail-safe requirements.
It is exceptionally robust and economical with low initial and low part replacement costs and is designed to have a long overhaul life with the minimum amount of maintenance. It is ideal for operating in areas without full scale maintenance facilities.
A newcomer to Armstrong Siddeley's great range of aero engines which includes such world-famous power units as the Sapphire, Viper and Double Mamba, the P.181 claims reliability, robustness and economy second to none in its class.

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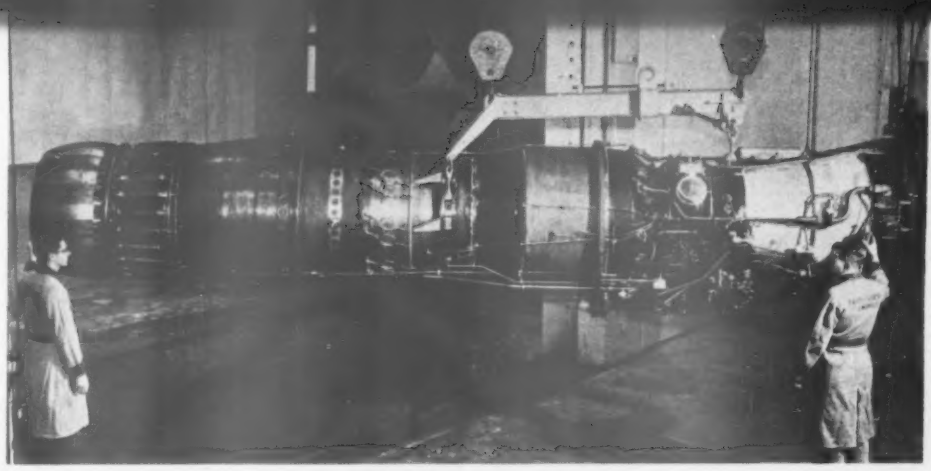

Right, a two-spool military turbojet widely used in America is the Pratt & Whitney J57. With afterburner (seen here) in operation, the thrust of the latest version is 17,000 lb.

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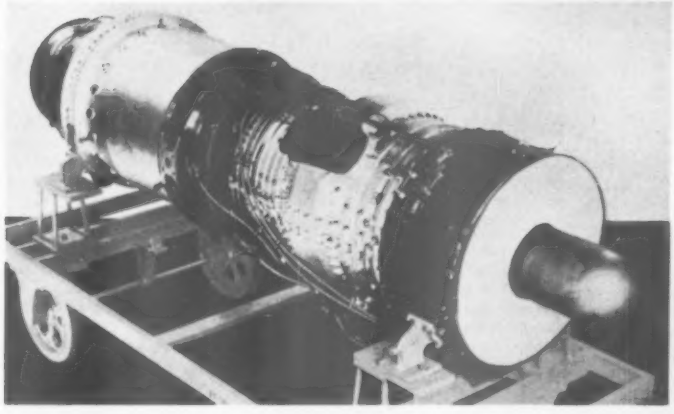
FIVE FROM THE U.S.A.

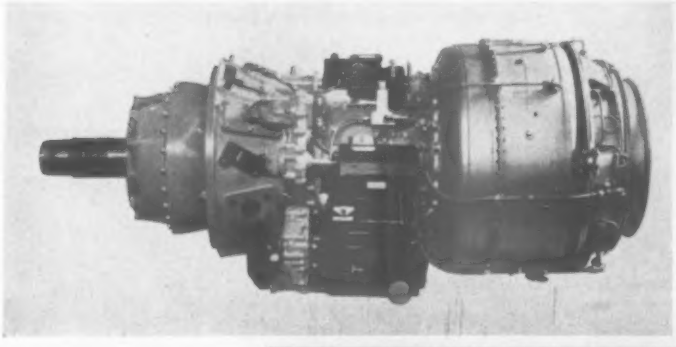


Above, most recent Westinghouse engine is the 6,500-lb. thrust J54 whose appearance shows obvious evidence of the technical link-up with Rolls-Royce.

Howard Levy photograph

Below, the turboprop version of the Lycoming T53 is to be used in the Grumman AO-1. It delivers 1,005 e.h.p. and weighs 495 lb.

Above, the smallest engine by Pratt & Whitney is the 3,000-lb. thrust JT12 turbojet. It has a thrust/weight ratio of 7.0:1 and will be used in four-engined versions of the Lockheed Jetstar.



Right, used in many of the latest American military aircraft, the General Electric J79 single-spool turbojet has a thrust of 18,000 lb. with afterburner in operation.

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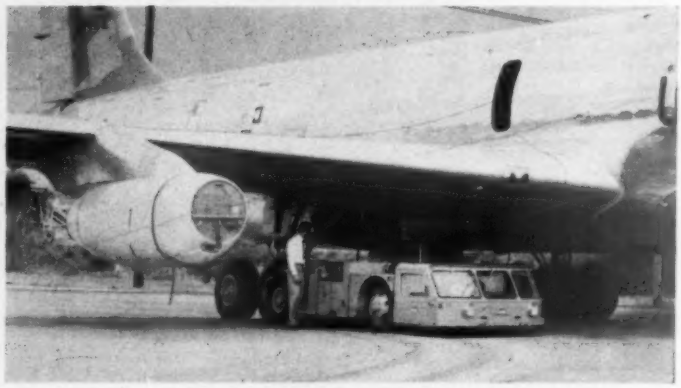
Gas Turbines for Special Duties



LOW-SLUNG TUG.—Two small Boeing gas turbines are installed in the Napco Turbo-Tug. A 502-10C gas turbine powers the vehicle, which will move aircraft weighing up to 500,000 lb., while a 502-11B air compressor supplies air for engine starting.

TO an increasing extent small gas turbines are being used for the starting and servicing of turbojet and turboprop aircraft and as airborne auxiliary power units. As with many trends in the aeronautical world, this new gas-turbine rôle was introduced in the military field and is now being extended to civil aircraft.

Low-pressure air starting for military aircraft was introduced in the U.S. Small gas-turbine units are used in ground trolleys to provide the compressed air for engine starting and servicing; with multi-engined aircraft, compressed air can be bled from the first engine to be started and used to start the others.

Airborne auxiliary power units make an aircraft independent of ground starting trucks and can provide emergency power at high altitude. Certain A.A.P.U.s can provide both compressed air and shaft power for driving generators, alternators or hydraulic pumps. Another advantage of the A.A.P.U. is that it can supply compressed air for ground air-conditioning and power for the ground testing of aircraft services without running an aircraft's main engines.

Another trend is towards the use of small gas-turbine engines in universal ground servicing units, which also provide electrical power for aircraft services, conditioned air for cabin cooling, heated air for cabin heating or for the removal of snow and ice from the airframe, compressed air for tyre inflation, etc. Servicing units on these lines have been proposed by Armstrong Siddeley and Blackburn. Another application is in small vehicles for towing aircraft.

It is claimed that a low-pressure air starting system made up of an air-turbine starter and a gas-turbine A.A.P.U. is considerably lighter than an electrical starting system. For a typical twin-engined aircraft, Armstrong Siddeley states that an electrical starting system weighs 1,200 lb. and is limited to six consecutive starts, while a self-contained system with an A.A.P.U. and an air-turbine starter weighs only 320 lb. and gives an unlimited number of starts.

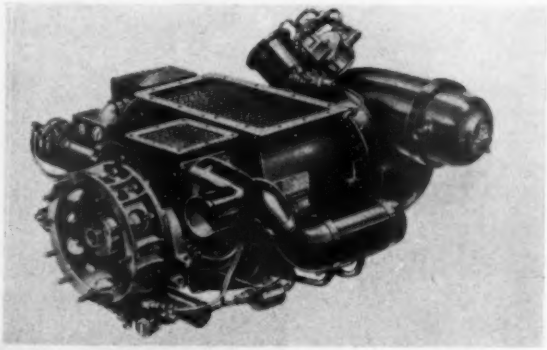
Why has there been this trend to compressed-air starting for aircraft? With the increase in engine power, electrical starting systems have become heavier and starting at low temperatures becomes difficult. Compressed air bled from the main engines has also been increasingly used for airframe services and it has been logical to extend this to engine starting.

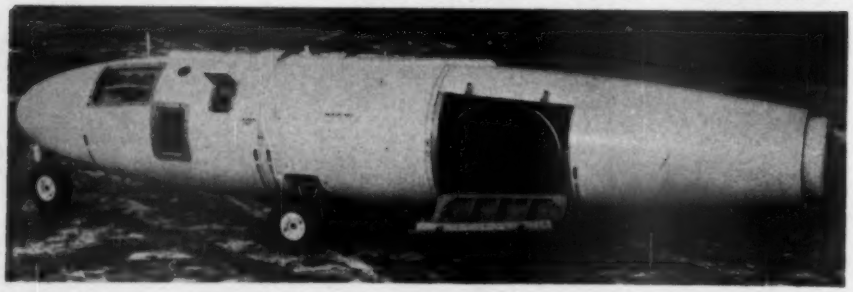
As compressed-air starting has been adopted for turbojet and turboprop aircraft, changes have been made in ground equipment. The demand for rapid and frequent starts in all ambient conditions, for relatively high power as engine sizes have increased, and for reasonable mobility, has tended to eliminate the reciprocating engine from the ground starting equipment for military aircraft. It has been replaced by the small and light, but powerful, gas-turbine unit. This has happened in the United States and is now coming to pass in Britain; low-pressure air starting is used on the latest Royal Navy aircraft and will also be used by the R.A.F. for the new versions of its V-bombers.

Now that small gas-turbines have an established place in the military field there is intense competition to introduce them for airline use. Commercial turbojet and turboprop aircraft have starting requirements similar to those of military aircraft, but there is considerably greater emphasis on low cost, reliability and competitive operating costs in civil ground-starting equipment.

The economics of these units will no doubt decide what the airlines choose. In this regard, it may be significant that Scandinavian Airlines System is conforming with the modern trend in using compressed-air starting for its DC-8s, but will use ground starter units which are rotary-screw air compressors driven by reciprocating petrol engines.

It is never easy to compare prices and operating costs of equipment, but the cost of air-starting units is indicated by Boeing figures. A gas-turbine compressor which will deliver





ONE OF MANY.—Above, more than 8,000 AiResearch gas turbines are in service as ground or airborne power units. This is the GTCP 85 which supplies both shaft power and compressed air.

PODDED STARTER. — This Blackburn Palouste air starter is built for air transport as an under-wing pod.

2 lb./sec. of air at 52 p.s.i.a., with the standard Ford van in which it is mounted, costs $15,700. Its overhaul period is about 500 running hours, or some 5,000 starts, and each start costs $1.60.

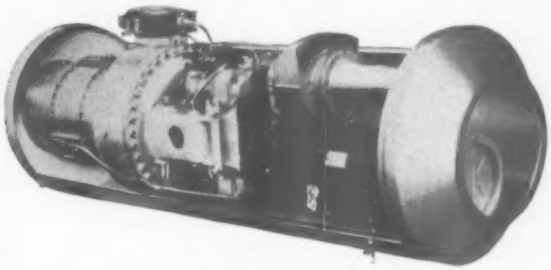
The small gas turbines used as compressed-air starter units and A.A.P.U.s have several technical features in common; all have centrifugal compressors, with the exception of the Solar Jupiter, although in some of the higher-powered units there are also axial stages. In consequence most of these gas turbines have a low pressure ratio. In nearly every case the compressed air is taken from an oversized compressor; the only exception is the Boeing 502-11B, a shaft-power unit which drives a separate compressor.

There is not enough space here to describe in detail the wide range of small gas-turbine units which are in production or being developed by British, French and American manufacturers. The account below outlines their products.

Britain

BLACKBURN AND GENERAL AIRCRAFT, LTD., has pioneered the British use of small gas turbines for compressed-air starting and as A.A.P.U.s. It has designed and developed a range of small gas turbines based on Turboméca patents. Although several of the Blackburn engines have the same name as the Turboméca engines on which they are based, they have been extensively redesigned and differ considerably in both appearance and performance.

Blackburn has produced four types of air-starting trolley; all embody a Palouste air-bleed engine. This delivers 2.71 lb./sec. of air at a pressure ratio of 3.88:1. The military versions of the Palouste are designated Bn.Pe.2 and 3. Blackburn starter trolleys have been ordered by the Royal Navy and the Royal



AIRBORNE POWER.—Enclosed in a cylindrical container, this Blackburn Artouste is an airborne auxiliary power unit which supplies compressed air and also drives a generator.

Canadian Air Force; three weeks ago the company announced that they had also been ordered by the R.A.F. for starting V-bombers. A Blackburn starter trolley has also been demonstrated at London Airport where for a fortnight it was used for air starting of Pan American Boeing 707s. A version of the Palouste air starter has been produced as an underwing pod which can easily be flown into forward airfields.

This company is also producing its Artouste 510, a combined shaft-power and air-bleed engine, for installation as an A.A.P.U. in a V-bomber and in the Canadair CL-44 and CL-66 transports. This engine weighs 338 lb. and will produce 190 b.h.p. plus an airflow of 1.4 lb./sec. at a pressure ratio of 4.00 : 1. If no shaft power is taken from it, the bleed airflow rises to a maximum of 2.5 lb./sec. at a pressure ratio of 3.72 : 1.

The latest Blackburn engine is the A.129, which has been developed initially as an 850 h.p. free-turbine helicopter powerplant. Later versions of the engine may be produced as an air-bleed and shaft-power A.A.P.U.

ARMSTRONG SIDDELEY MOTORS, LTD., has a licence to produce the AiResearch range of air-turbine starters and auxiliary power units which can be used either as A.A.P.U.s or in ground applications. These AiResearch units are extensively used on American military aircraft and cover powers ranging from 30 to 850 h.p. Details of the range were given in our issue of July 25, 1958.

AUTO DIESELS, LTD., has entered the low-pressure air-starter field with a gas-turbine starter trolley using a 250 h.p. gas turbine produced by the Standard Motor Co., Ltd. This has been designed to deliver 2 lb./sec. of air at a pressure of 55±2 p.s.i.a. The unit has successfully completed a cyclic endurance test which simulated 6,000 engine starts. An order for it has been received from the Ministry of Supply and this starter, the AYDEE, model L.P.1, will be used by the R.A.F.

ROVER GAS TURBINES, LTD., exhibited at Farnborough last year an auxiliary power unit intended for either ground or airborne use. This was the Rover 1S/60, which has been designed to provide both emergency electric power and a supply of compressed air for engine starting. It weighs 400 lb. and produces 32kW. of power at sea level. Its air bleed flow, 0.875 lb./sec. at 48 p.s.i.a., is considerably lower than that of the average low-pressure air-starting trolley, which supplies about 2 lb./sec. This Rover unit is at present under development.

France

SOCIETE TURBOMECA was one of the earliest manufacturers to produce successful small gas-turbine engines, and licences for the production of engines based on these have been taken out both in Britain by Blackburn and in the U.S. by the Continental Company.

Although developed versions of Turboméca engines have been produced for low-pressure air starting in Britain and the U.S., the Turboméca engines have found wider application in their native France as primary powerplants for aircraft. While the Blackburn version of the Artouste is produced as an A.A.P.U., the Turboméca Artouste is best known as the shaft turbine which powers the Alouette helicopter.

Two Turboméca engines which represent a considerable advance on the company's early units are the Autan 2, a high-pressure air-bleed engine which supplies 3 lb./sec. of air at a 5 : 1 pressure ratio, and the Tramontane turbo-generator or air compressor. This delivers 5.5 lb./sec. of air at a pressure ratio of 3.5 : 1.

U.S.A.

THE AIRESEARCH MANUFACTURING DIVISION of the GARRETT CORPORATION was one of the earliest U.S. manufacturers in the low-pressure air-starting field and now produces a wide range of A.P.U.s which are installed in a variety of U.S. military aircraft as well as used in ground installations. Some 8,000 of its gas-turbines are in service either for ground duties or as A.A.P.U.s.

THE BOEING INDUSTRIAL PRODUCTS DIVISION has produced a range of gas-turbine units based on its Model 502, which was designed basically as an industrial engine with emphasis on long life and reliability rather than the light-weight and compactness of airborne units. Shaft-drive units derived from this engine are the 502-10C and 502-10F, while the 502 driving a centrifugal compressor—and known in this form as the 502-11B—has been used as a military low-pressure air starter for about five years. This is the starter for the B-52 strategic bomber.

For civil use the 502-11B has been mounted in a standard Ford van and is known as the Turbo-Starter. It delivers 2 lb./sec. of air at 52 p.s.i.a. Turbo-Starters have been ordered by United, Delta and Pan American Airways. A later Boeing unit is the 514 which is a 5.5 : 1 compression-ratio shaft turbine designed either for ground duties or for use as an A.A.P.U.

THE GAS TURBINE DIVISION of the CONTINENTAL AVIATION AND ENGINEERING CORPORATION holds a U.S. licence to produce the Turboméca range of gas turbines. The Continental 141 has been developed from the Turboméca Palouste and has been produced as a ground-starter unit for jet aircraft; it delivers 2.2 lb./sec. of air at 52.5 p.s.i.a.

THE SOLAR AIRCRAFT CO., produces a range of small gas turbines. The Mars develops about 50 h.p. and weighs about 100 lb.; it is used as an A.A.P.U. in the KC-97 transport. Both the Mars and the 500-h.p. Jupiter are in quantity production. Air-bleed versions of the Jupiter, which is an axial-flow unit, are to be used as truck-mounted units for starting the B-58 Hustler bomber.

INDUSTRIAL APPROACH.—This low-pressure air-starter trolley produced by Auto-Diesels Ltd. embodies a 250-h.p. Rover industrial gas-turbine.

Powerplant Survey . . . .

Jet Engine Noise

THE noise of aircraft taking off and landing at London Airport nearly deafened the audience at the beginning of a Royal Aeronautical Society lecture on January 27 by Mr. P. Lloyd, C.B.E., M.A., A.F.R.Ae.S., deputy director of the National Gas Turbine Establishment. Mr. Lloyd's effective introduction to his talk was to play tape-recordings of a Super Constellation, Britannia, Comet 4 and Boeing 707 taking off and landing at London Airport.

The noise was recorded 2¼ miles from the start of the take-off run for the Boeing 707 and two miles away for the other aircraft. For a Super Constellation taking off at 77% maximum all-up weight, a height of 472 ft. was reached over the recording point and the maximum noise level was 102 db. Corresponding figures for the Britannia were 72% a.u.w., 613 ft. and 101 db.; for the Comet 4, 99% a.u.w., 1,040 ft. and 104 db.; for the Boeing 707, 99% a.u.w., 428 ft. and 116 db.

The recordings of landing noise were corrected relative to a point 3,000 ft. from the runway threshold and a height of 180 ft. They were actually measured 3,000 ft. away for the Boeing 707 and 1,500 ft. away for the other aircraft. The respective noise levels were 106 db. for the Super Constellation, 98 db. for the Britannia, 105 db. for the Comet 4 and no less than 125 db. for the Boeing. As each 3-db. increase in sound pressure level is equivalent to doubling the intensity of the sound, the importance of landing noise is evident; it is considerably greater for jet aircraft than the take-off noise.

Mr. Lloyd pointed out the different quality of the noise made by the various aircraft and commended the Bolt Beranek noise studies made for the Port of New York Authority. In these the subjective effect of noise was assessed to find the relative annoyance produced by various sound levels. The concept of the perceived noise level in decibels, the PNdb., had been introduced; this gave a measure of the annoyance produced by a noise. A perceived noise level of 100 PNdb. sounds as noisy to an observer as a mid-octave-band noise of 100 db.

But greater annoyance is produced by high-frequency noise which can have an "annoyance level" up to 20 PNdb. greater than its scientifically measured value in db. A change of 5 PNdb. is equivalent to about a 50% increase in subjective noisiness, 10 PNdb. to a 100% increase and 16 PNdb. to a 200% increase.

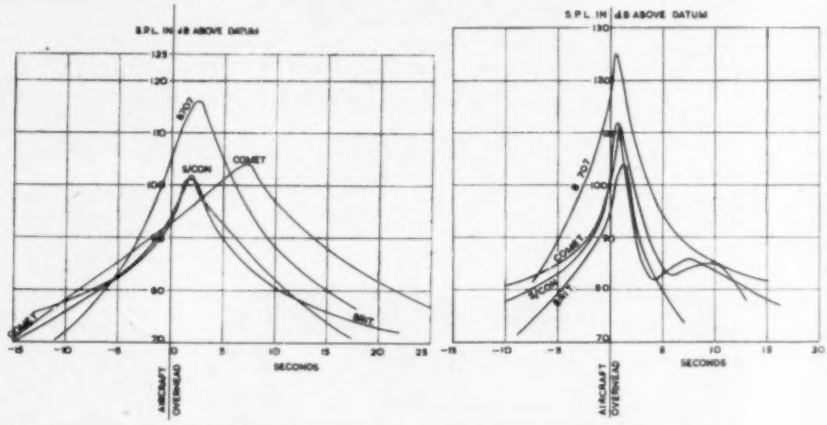
Mr. Lloyd compared plots of PNdb. for the Comet 4 and Boeing 707, which in both cases had a higher annoyance level on landing. He also spoke of Beranek studies of the effect of increasing altitude; this had a big effect on the attenuation of the higher-frequency noise which had the greater annoyance value.

a 10,000-lb.-thrust engine was 124 PNdb. and 107 db.

PROFESSOR J. RICHARDS of Southampton agreed that the concept of the perceived noise level was a big advance. More attention should be given to designing engines which brought the noise frequency down; most silencers raised the frequency. The perceived noise level concept threw silencing-nozzle design right out of court.

MR. M. B. MORGAN, deputy director of the R.A.E., said that silencing nozzles had succeeded in making the jet noisier to the human ear. He asked about supersonic-aircraft noise problems.

Mr. Lloyd replied that supersonic aircraft needed hot high-velocity engines which would therefore be very noisy. There was a threat of an 8-db. increase



LONDON AIRPORT NOISE.—These noise levels were recorded last month for aircraft taking off (left) and landing (right) at London Airport. Recording distances, peak noise levels and aircraft heights and weights are given in the text.

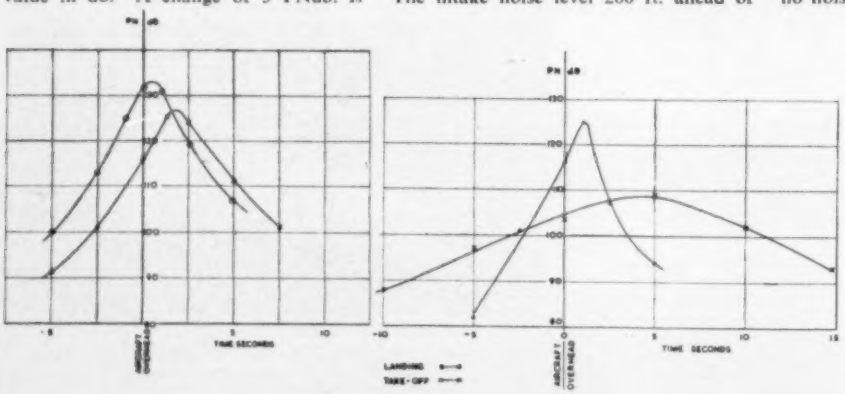
Mr. Lloyd said that the ducted-fan type had an important part to play in future. A ducted fan was an engine whose fan system had a mass flow at least as great as that of the high-pressure compressor. These engines might be bigger, heavier and more difficult to install than their conventional counterparts, but they offered a real solution to the noise problem and also overall advantages in economy for subsonic flight. The noise rating of a ducted-fan engine with a by-pass ratio of two could be 20 db. less than for a conventional turbojet.

The big difficulty was intake noise, about which very little was known; the only available information was on the noise of propellers and ventilating fans. The intake noise level 200 ft. ahead of

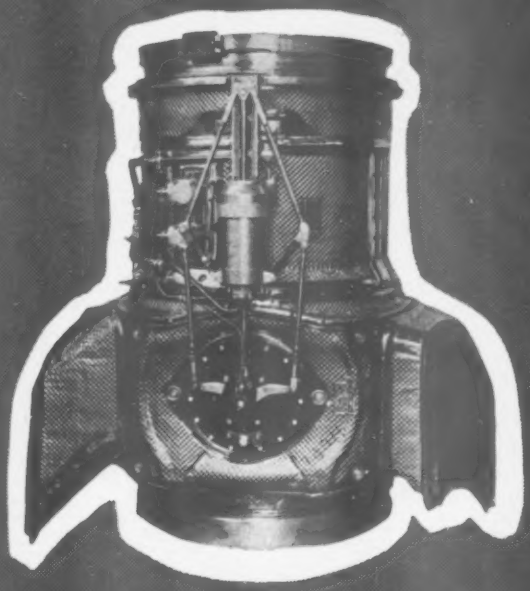
in noise over subsonic aircraft. But, fortunately, noise was now taken seriously; it was better to design for low noise levels from the start rather than to take emergency measures.

MR. G. H. LEE, Handley Page deputy chief designer, asked whether intake noise could be eliminated by producing a plane shock-wave in the intake. Mr. Lloyd said that this might be possible, or an alternative might be a shock in the blade passages.

DR. G. E. BELL, of the Ministry of Transport and Civil Aviation operational research branch, said that present-day large piston-engined aircraft were approaching the noise limit and the trend was to insist that later aircraft should be no noisier over built-up areas.



JET AIRLINERS COMPARED.—Noise records for the Boeing 707 (left) and the Comet 4 are compared in PNdb. or "annoyance-level" decibels. The relevant recording distances and peak noise levels in db. are those given in the text; note that Boeing 707 records were made at a greater distance than those for the Comet 4.



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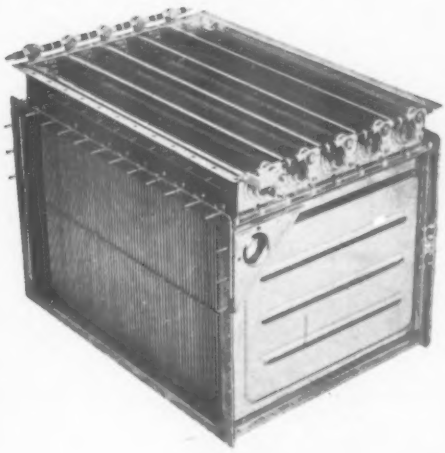
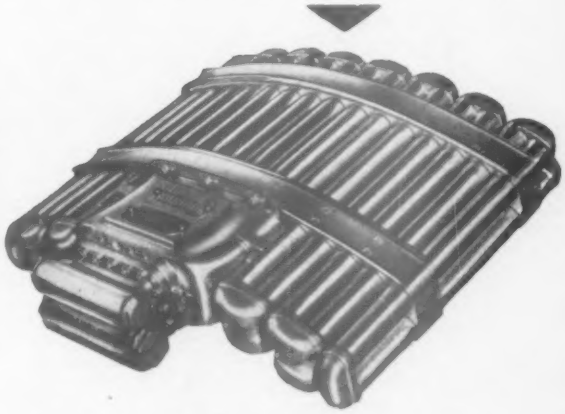
High pressure fuel-cooled oil coolers for high performance gas turbine engines. This unit is used in the Armstrong Siddeley Sapphire S.A.7.



Heat exchangers for many purposes in both aluminium alloy and stainless steel. This particular example is for the Vickers Vanguard's anti-icing system. Similar units are being supplied for the Fokker Friendship, the Bristol Britannia, the Armstrong Whitworth Argosy, the Vickers Viscount and the Handley Page Herald.



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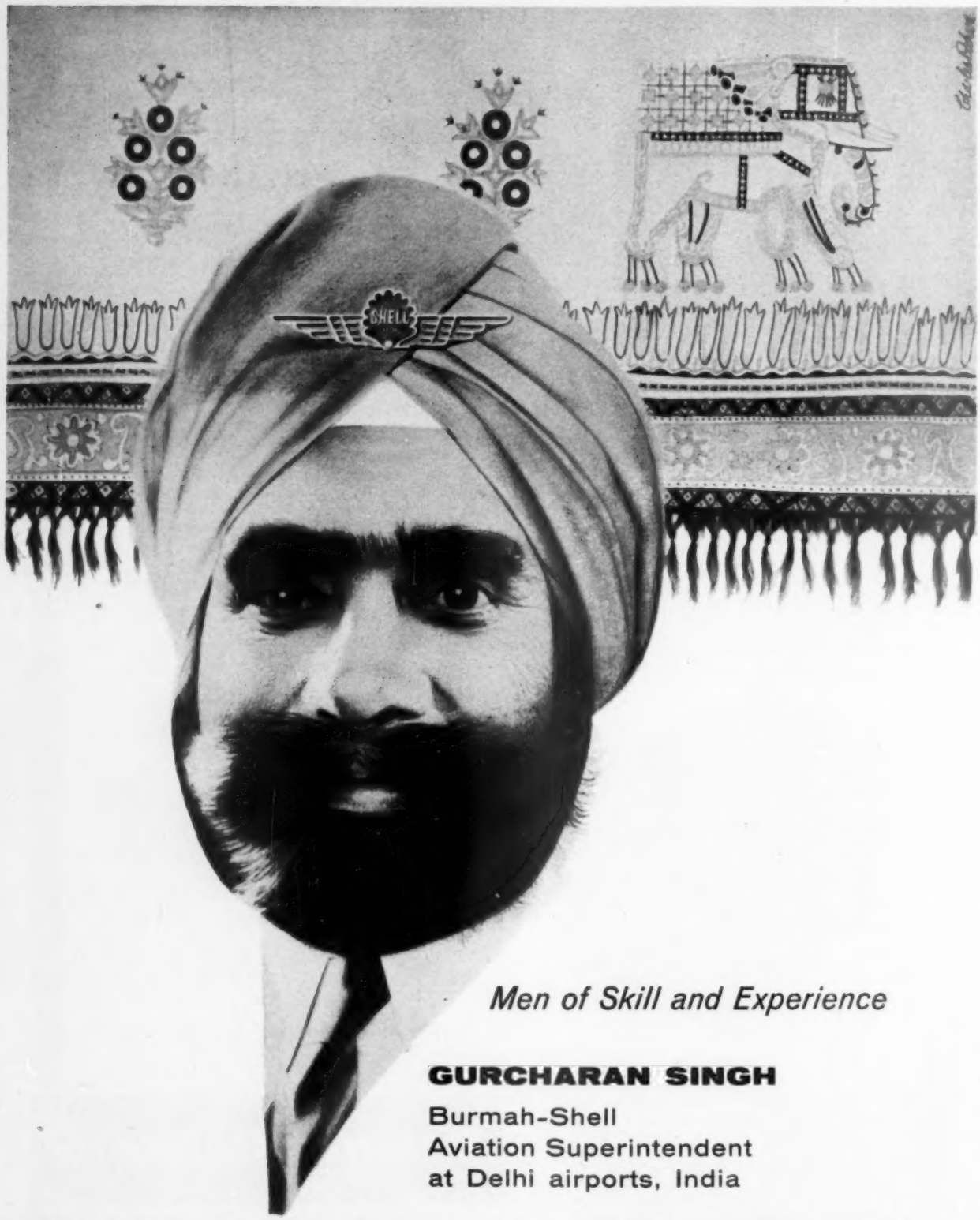

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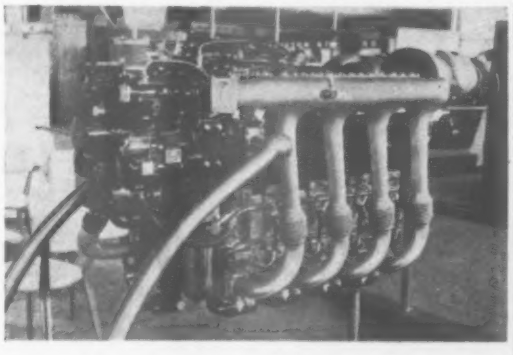
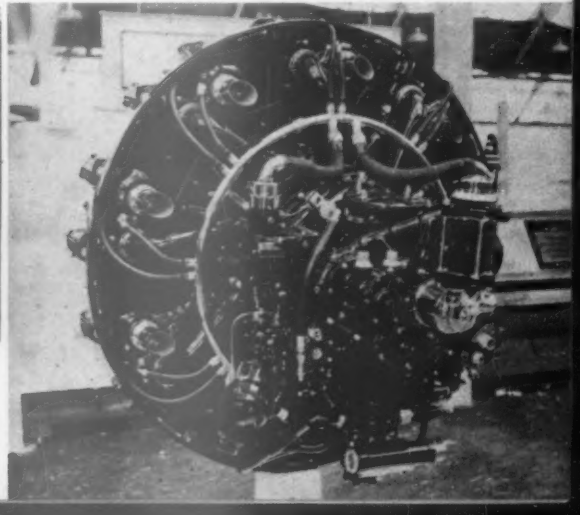
Powerplant Survey . . . .

Piston Engine Data

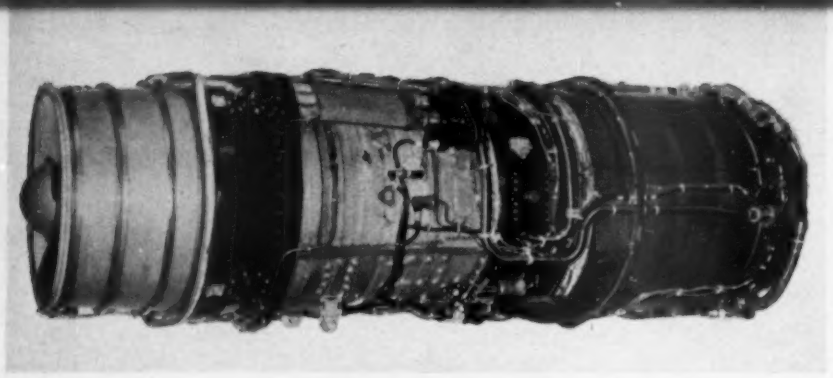
Engine Make and name	Type	No. of cyls.	Dimensions: Swept volume	Length	Width	Height	Dry weight	Comp. ratio	Performance: Take-off b.h.p.	Take-off r.p.m.	Max. continuous b.h.p.	Max. continuous r.p.m.	Max. continuous ft.	Fuel consumption
			cu. in.	in.	in.	in.	lb.		b.h.p.	r.p.m.	b.h.p.	r.p.m.	ft.	g.p.h.
CZECHOSLOVAKIA														
Walter Minor 5c. (M 332)	I.L.	4	249	43.4	16.7	24.7	225	6.3 : 1	140	2,700	115	2,550	S.L.	0.45 lb.
Minor 6-111	I.L.	6	354	49.21	17.49	25.16	280	6 : 1	160	2,500	N.A.	N.A.	N.A.	0.49 lb.
Praga Doris B	H.O.	6	437	48.38	36.81	24.06	436	7 : 1	220	3,000	200	2,900	S.L.	0.46 lb.
FRANCE														
Ardem (Druine) 4 CO 2	H.O.	4	72.62	16.0	30.0	25.0	133(P)	6 6 : 1	30.7	3,000	N.A.	N.A.	N.A.	1.75
Potez 4-D30	I.L.	4	352	48.0	20.87	28.35	403	7 : 1	240	2,550	205	2,400	2,300	0.49 lb.
6-D30	I.L.	6	539	61.0	20.87	28.35	573	7 : 1	325	2,400	260	2,400	S.L.	0.51 lb.
8-D32	I.L.	8	719	66.3	31.3	31.6	738	7 : 1	520	2,650	430	2,650	S.L.	0.49 lb.
Snecma (Bristol) Hercules 758	2R.	14	2,360	N.A.	52.0	52.0	2,175	7 : 1	2,040	2,800	1,670	2,500	5,000	N.A.
Renault 12T	I.L.	12	N.A.	53.7	19.6	29.7	N.A.	N.A.	600	3,300	506	3,250	7,850	18.4
GERMANY														
Porsche 678/0	H.O.	4	96.5	N.A.	N.A.	N.A.	192	7.5 : 1	65	4,500	55	4,200	S.L.	3.52
ITALY														
Agusta G.A.40	H.O.	2	90.68	24.09	30.9	15.35	95	7.2 : 1	42	2,700	N.A.	N.A.	N.A	N.A.
G.A.70/0 (and 70/V*)	H.O.	4	140.4	29.53	29.33	17.72	163	7.2 : 1	83	3,500	N.A.	N.A.	N.A	N.A.
JAPAN														
Kawasaki KAE-240	H.O.	6	448	N.A.	N.A.	N.A.	N.A.	N.A.	260	3,400	N.A.	N.A.	N..	N.A.
POLAND														
Narkiewicz WN-3	R.	7	820	34.9	43.5	43.5	530	6.2 : 1	320	2,350	285	2,250	S.L.	0.48 lb.
WN-6	H.O.	6	421	42.9	32.67	16.53	346	6.5 : 1	180	2,600	160	2,500	S.L.	0.48 lb.
WN-7	H.O.	4	281	37.0	32.67	20.47	232	6.5 : 1	125	2,500	110	2,350	S.L.	0.47 lb.
SPAIN														
Enma Flecha F-IV-1	H.O.	4	211	31.84	31.64	28.65	220	7 : 1	93	2,600	N.A.	N.A.	N.A.	0.51 lb.
Tigre G-IV-B5	I.L.	4	386	47.67	15.76	29.82	323	6.33 : 1	150	2,300	N.A.	N.A.	N.A.	0.50 lb.
Alcion A-1	R.	7	446	45.9	33.46	33.46	495	6.5 : 1	275	3,000	250	2,800	4,920	0.46 lb.
Sirio S-2	R.	7	1,090	45.7	44.1	44.1	785	6 : 1	500	2,300	440	2,100	6,890	0.50 lb.
Beta B-4	R.	9	1,820	46.0	54.6	54.6	1,070	6.4 : 1	775	2,200	750	2,100	9,500	0.55 lb.
UNITED KINGDOM														
Alvis Leonides 514/8	R.	9	718.6	54.4	41.5	41.5	810	6.5 : 1	540	3,000	500	2,900	3,750	23.5
Leonides 524/1*	R.	9	718.6	52.8	41.5	41.5	730	6.5 : 1	500	3,000	390	2,800	9,250	N.A.
Leonides 530	R.	9	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	600	N.A.	N.A.	N.A.	N.A.	N.A.
Leonides Major Mk. 155*	2R.	14	1,118	54.9	38.9	38.9	1,050	6.8 : 1	780	2,900	705	2,900	6,750	42.0
Blackburn Bombardier 703/203	I.L.	4	398	45.3	18.6	31.0	379	7 : 1	180‡	2,600	158	2,300	1,250	10.5
Bristol Centaurus 661	2R.	18	3,270	74.6	55.3	55.3	3,460	7.2 : 1	2,625	2,800	2,265(M) 2,110(S)	2,500(M) 2,500(S)	5,500(M) 12,000(S)	85.0
De Havilland Gipsy Queen 70/2	I.L.	6	622	71.75	19.56	33.23	690	6.5 : 1	380	3,000	355	2,700	4,250	17.5
Gipsy Major 215*	I.L.	4	416	51.0	16.8	29.8	400	7.25 : 1	215	2,850	207	2,700	S.L.	10.0
Rolls-Royce Griffon Mk. 57	I.L.	12	2,240	83.5	31.8	N.A.	2,115	6 : 1	2,435	2,750	1,355(M) 1,285(S)	2,400(M) 2,400(S)	6,250(M) 12,500(S)	124.0
U.S.A.														
Continental A65-8F	H.O.	4	171	29.0	31.50	20.30	173	6.3 : 1	65	2,300	65	2,300	S.L.	4.0
C90-12F	H.O.	4	201	31.25	31.50	21.20	186.5	7 : 1	95	2,625	90	2,475	S.L.	0.53 lb.
O-300-A and B	H.O.	6	301	36.40	31.50	22.50	276.5	7 : 1	145	2,700	145	2,700	S.L.	0.50 lb.
O-470-K and L	H.O.	6	471	36.00	33.60	27.80	404	7 : 1	230	2,600	230	2,600	S.L.	0.52 lb.
Franklin 335 (and 335V*)	H.O.	6	335	27.41	N.A.	N.A.	320	7 : 1	165	2,800	N.A.	N.A.	N.A.	0.50 lb.
425*	V.O.	6	425	39.22	33.28	38.0	352	7.5 : 1	245	3,275	N.A.	N.A.	N.A.	0.52 lb.
Lycoming O-235-C1	H.O.	4	233	29.55	32.0	22.53	237	6.75 : 1	115	2,800	108	2,600	S.L.	0.52 lb
O-290-D2B	H.O.	4	289	29.56	32.24	22.81	264	7 : 1	140	2,800	135	2,600	S.L.	6.5
O-340-B1A	H.O.	4	340.4	29.56	32.55	24.68	275	7.5 : 1	160	2,700	160	2,700	S.L.	8.5
O-435-A (and VO-435*)	H.O.	6	434	38.10	32.24	29.59	392	6.5 : 1	190	2,550	190	2,550	S.L.	0.52 lb.
GSO-480-B1A6	H.O.	6	479.7	46.22	33.12	29.40	498	7.3 : 1	340	3,400	320	3,200	7,500	16.0
VO-540-A1A	V.O.	6	541.5	34.73	34.44	28.18	435	N.A.	310	N.A.	305	N.A.	N.A.	N.A.
SO-580-A1B	H.O.	8	578	46.62	33.12	24.49	578	7.3 : 1	400	3,300	350	3,000	S.L.	16.5
VSO-580-3*	V.O.	8	578	N.A.	33.18	30.75	591	7.3 : 1	400	3,300	350	3,000	S.L.	N.A.
McCulloch 431PB	H.O.	4	100	27.00	22.00	15.0	77	7.8 : 1	72	4,100	72	4,100	S.L.	0.90 lb.
TC6150	H.O.	6	150	44.50	22.00	17.0	142	7.8 : 1	120	N.A.	86	N.A.	30,000	0.80 lb.
Nelson H-63	H.O.	4	63	18.00	25.00	17.5	60	8 : 1	42	4,000	42	4,000	S.L.	5.5
Pratt & Whitney R-1340	R.	9	1,344	43.01	51.80	51.8	865	6 : 1	600	2,250	550	2,200	8,000	N.A.
R-2000 D5	2R.	14	2,004	59.66	49.10	49.1	1,585	6.5 : 1	1,450	2,700	1,200	2,550	6,400	N.A.
R-2800 CB17	2R.	18	2,804	81.40	52.80	52.80	2,390	6.75 : 1	2,500†	2,800	1,900(M) 1,750(S)	2,600(M) 2,600(S)	7,000(M) 13,500(S)	N.A.
Wright R-1820-82	R.	9	1,823	50.10	55.74	55.74	1,469	6.8 : 1	1,525	2,800	1,275(M) 1,125(S)	2,500(M) 2,500(S)	3,500(M) 10,600(S)	0.68 lb.
R-3350 TC18EA6	2R	18	3,347	89.53	56.59	56.59	3,675	6.7 : 1	3,440	2,900	2,920(M) 2,450(S)	2,650(M) 2,600(S)	4,800(M) 16,400(S)	N.A.
U.S.S.R.														
ASR-92T	2R.	14	2,513	79.13	51.18	51.18	2,250	6.9 : 1	1,900	2,600	1,630	2,400	5,250	N.A.
M-11RF	R.	5	522.6	37.4	42.5	42.5	353	5.0 : 1	160	2,000	N.A.	N.A.	N.A.	0.55 lb.

Abbreviations.—H.O., horizontally-opposed; I.L., in-line; *lb.*, lb/b.h.p./hr.; (M), medium supercharger speed; N.A., not available; (P), with propeller and exhaust stubs; (S), fast supercharger speed; S.L., sea level; R., radial; * helicopter engine; †, with coolant injection; ‡ max. 5 min. limit; V.O., vertically opposed.





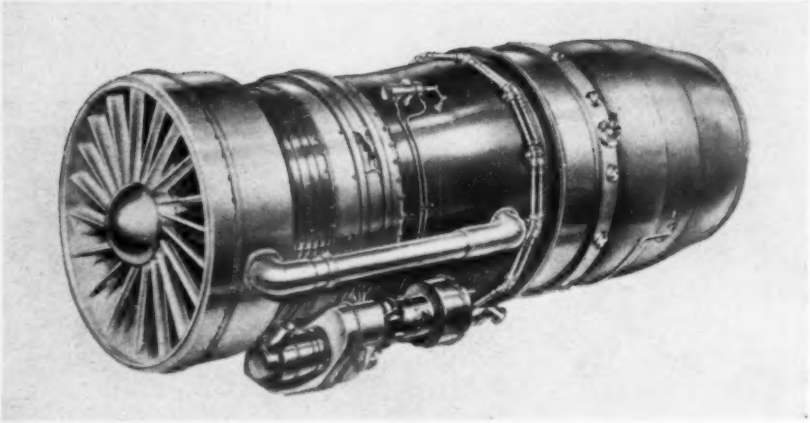
BRITISH RECIPROCATORS.—The de Havilland Gipsy Major 200 in-line engine and the Alvis Leonides 530 radial engine.

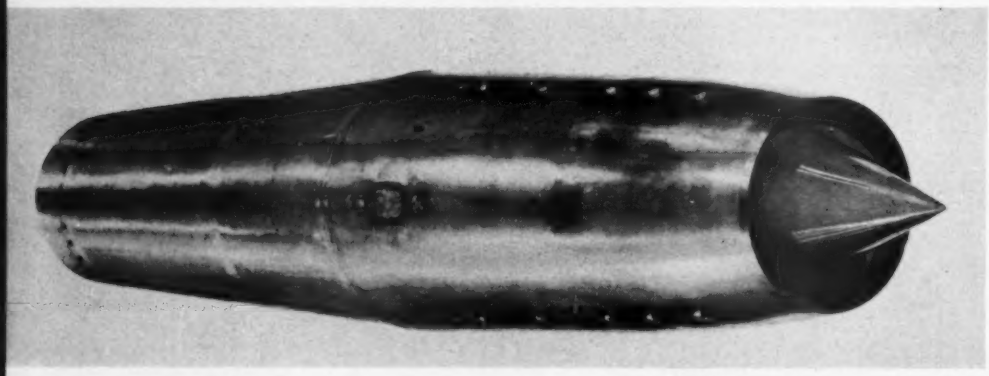


Left, the 11,000-lb. thrust Armstrong Siddeley Sapphire A.S.Sa.7R turbojet develops 12,300 lb. with afterburning.

Powerplant Survey . . . .

BRITISH QUINTET

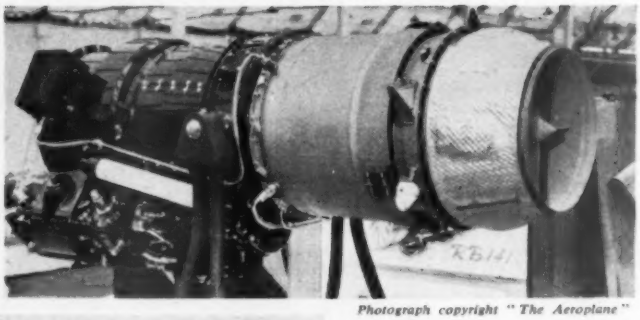




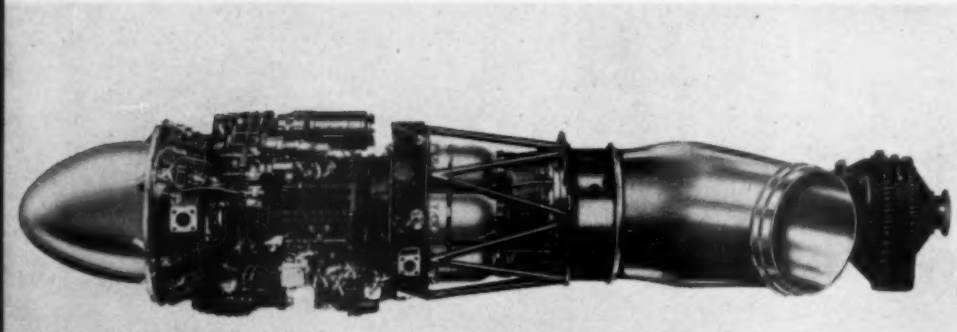
Above, an impression of the Rolls-Royce R.B.141 civil by-pass turbojet of about 12,000-lb. thrust which is under development for the de Havilland D.H.121.

Above, the Bristol Thor ramjet, two of which form the powerplant of the Bristol/Ferranti Bloodhound surface-to-air guided weapon.

Right, latest Rolls-Royce engine is the 2,750-lb. thrust R.B.145 turbojet. Derived from the R.B.108 VTOL engine, it is of similarly high thrust/weight ratio.

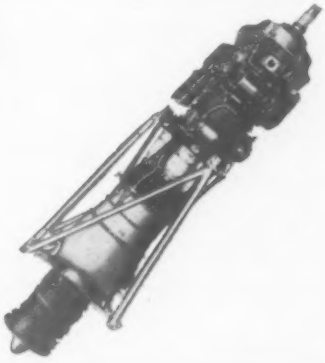


Photograph copyright "The Aeroplane"



Left, the Napier Eland shaft turbine as used in the Westland Westminster helicopter. On the right of the engine is the hydraulic clutch unit.

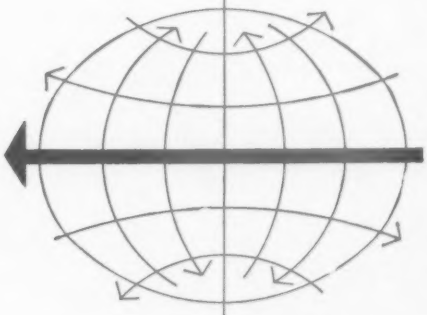
ELAND (*for fixed-wing aircraft*). Propeller-turbine engine for new airliners and conversions of piston-engined airliners to propeller-turbine power. Chosen for the Canadair 540.



ELAND (*for helicopters*). Specially designed for the Fairey Rotodyne. Basically a standard Eland with an auxiliary compressor mounted at the rear.

ELAND (*for helicopters*). Specially designed for the Westland Westminster. Basically a standard Eland with the propeller and propeller reduction gear removed and a rear-drive shaft added.

NAPIER AERO ENGINES



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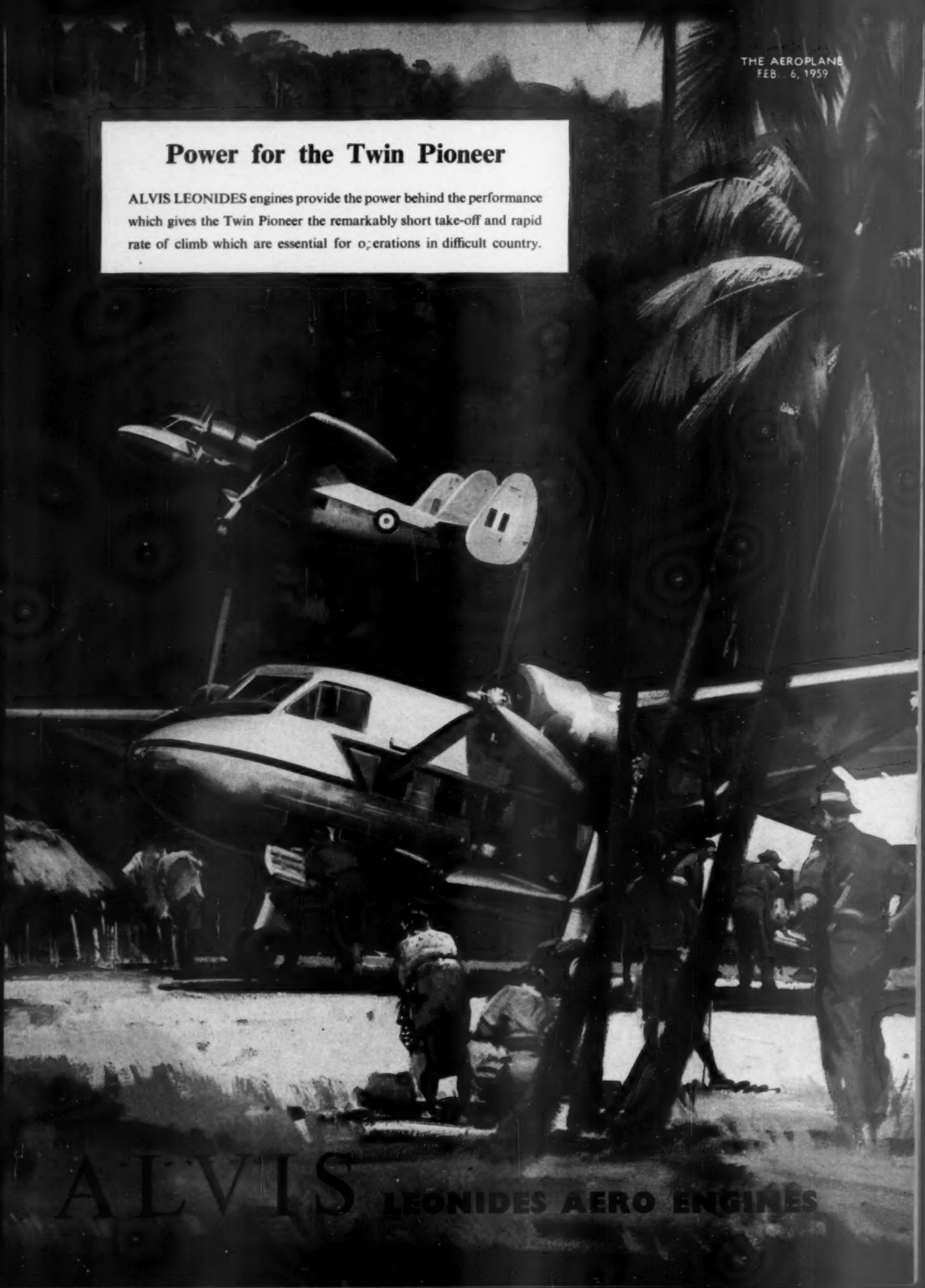


ALVIS LEONIDES AERO ENGINES

The Fighting Services

Flag Officer Changes

ON taking up his new appointment of Commander-in-Chief, Mediterranean, on February 2, Admiral Sir Alexander Bingley, K.C.B., O.B.E., became the first C.-in-C. in Malta to wear the observer's wings of the Fleet Air Arm. Made a K.C.B. in the New Year Honours and knighted by special dispensation on January 26, Admiral Bingley relinquished his command of the Aircraft Carrier Squadron to Rear Admiral C. L. G. Evans, C.B., C.B.E., D.S.O., D.S.C., on January 13.

In succeeding Admiral Sir Charles Lambe as C.-in-C., Mediterranean, Admiral Bingley has also assumed the NATO post of C.-in-C., Allied Forces, Mediterranean. Appointed to command H.M.S. "Eagle" in 1952, he was promoted to flag rank in 1954 and made Fifth Sea Lord and Deputy Chief of Naval Staff (Air). He became Flag Officer Aircraft Carriers in January of last year.

Before his new appointment, Rear Admiral Evans was Flag Officer Flying Training, before which he was Deputy Chief of Naval Personnel (Officers) at the Admiralty.

Guy Gibson Scholarship

THE second Guy Gibson Scholarship endowed by the Air Council at St. Edward's School, Oxford, and named after Wg. Cdr. Guy Gibson, V.C., D.S.O., D.F.C., an old boy of the school, will become available in September. The Scholarship, worth £40 a year, was first awarded in 1956, in recognition of the close ties existing between the school and the Service, and goes to the son of a serving R.A.F. officer for the duration of his time at the school. The first holder of the Scholarship was M. S. J. McKinley, son of Air Cdre. D. C. McKinley, C.B.E., D.F.C., A.F.C.

More than 250 old boys from St. Edward's School have served in the R.A.F., of whom some 170 have held commissions and many have achieved distinction with the Service. Applications for the scholarship should be submitted before March 1 to the secretary, R.A.F. Benevolent Fund, 67 Portland Place, London, W.1.

Middle East Posting

GROUP CAPTAIN A. A. F. HICKMAN, O.B.E., has recently relinquished the appointment of Senior Training Officer at No. 4 School of Technical Training, R.A.F. St. Athan, to become Senior Technical Staff Officer, M.E.A.F., with the acting rank of Air Cdre. Senior Technical Staff Officer with the Rhodesian Air Training Group in 1951, Gp. Capt. Hickman took over command of R.A.F. Henlow in 1952. He became Chief Aircraft Supply Liaison Officer to the M.o.S. in October, 1954.

A.D.C. to Her Majesty

GROUP CAPTAIN K. W. GODFREY, C.B., C.B.E., has been appointed Aide-de-Camp to H.M. The Queen with effect from November 29, 1958, in succession to Air Cdre. F. J. A. Tanner. Deputy Director of Ground Defence at the Air Ministry since April, 1955, Gp. Capt. Godfrey is to become Director of Ground Defence with the acting rank of Air Cdre. on March 1.

R.A.F. Appointments

THE following are among recent Royal Air Force appointments:—

Wing Commanders: H. W. G. Andrews, D.F.C., to SHAPE; A. R. Atkins to Headquarters, Transport Command, for technical staff duties; A. S. Baker, D.F.C., to R.A.F. North Front, Gibraltar, to command No. 224 Sqn.; E. F. Hales to Air Ministry for duty in the Department of the Air Member for Supply and Organization; G. S. W. Kerslake, M.B.E., to R.A.F. Benson for technical duties; C. W. Lovatt to Air Ministry for duty in the Department of the Air Member for Supply and Organization; L. A. Malins, D.S.O., D.F.C., to the U.S.A.F. on exchange posting; R. P. Norman to Headquarters, Fighter Command, for administrative staff duties; C. Pattison to Air Ministry for duty in the Department of the Air member for Supply and Organization; F. W. T. Pryer, O.B.E., to Headquarters, Home Command, for administrative duties; F. C. Woolley, M.B.E., to Headquarters, Signals Command, for engineering duties.

Squadron Leaders: W. A. Appleton to No. 32 M.U. as Senior Technical Officer (with acting rank of Wg. Cdr.); J. H. Hedger to Air Ministry for duty in the Department of the Air Member for Supply and Organization (with acting rank of Wg. Cdr.); K. L. Monaghan, D.F.C., D.F.M., to No. 12 M.U. to command (with acting rank of Wg. Cdr.); A. A. Storar to No. 402 Air Stores Park, R.A.F. Germany (2nd T.A.F.), to command (with acting rank of Wg. Cdr.).

CARRIER COMMAND.—As recorded above, Rear Admiral C. L. G. Evans, C.B., C.B.E., D.S.O., D.S.C., succeeded Admiral Sir Alexander Bingley, K.C.B., O.B.E., as Flag Officer Aircraft Carriers on January 13. Above, then Vice-Admiral Bingley (left) with Rear Admiral Evans on board H.M.S. "Eagle."

BEDFORD PILOTS.—Below, members of the Flying Wing at R.A.E., Bedford. Left to right, sitting, Lieut. Cdr. P. I. Normand; Sqn. Ldr. S. J. Hubbard, D.F.C., A.F.C.; Wg. Cdr. S. McCreith, A.F.C. (C.O.); Sqn. Ldr. B. J. L. Greenland, A.F.C., and Mr. D. J. Tayler, D.F.C.; standing, Flt. Lt. L. W. F. Stark, D.F.C., A.F.C.; Flt. Lt. P. B. Rea; Flt. Lt. A. J. Camp, A.F.C.; Flt. Lt. M. S. Goodfellow; Lieut. Cdr. J. S. Humphreys; Flt. Lt. A. Bountiff, and Flt. Lt. F. W. Bell.

More About NASA's Space Capsule

DETAILS of Project Mercury, the NASA "man-in-space" programme for which McDonnell Aircraft is to build the manned space capsule, have now been given. Management and technical direction of Project Mercury are the responsibility of the NASA, which will receive advice and assistance from the Advanced Research Projects Agency of the U.S. Defence Dept. The Administration's Space Task Group, which is in charge of the programme, was set up in October, 1958 at Langley Research Center, Virginia.

Project Mercury aims to put a manned space capsule into orbital flight around the Earth, to recover this capsule and its occupant successfully and to investigate man's capabilities in this new environment. The flight plan calls for an ICBM booster to launch the capsule into a near-circular orbit at an altitude of 100 to 150 miles to give the satellite a life of 24 hours. Re-entry will be started by retro-rockets incorporated in the capsule and parachutes will be used after the vehicle has been slowed by aerodynamic drag.

The non-lifting capsule will be designed to have high aerodynamic drag and be statically stable over the Mach-number range which applies to flight in the atmosphere. It will have an extremely blunt leading edge covered with a heat shield.

Twelve pilots will be specially trained. Each must be "in superb condition." They will be trained U.S. test pilots, with at least 1,500 flying hours, and university graduates in engineering or physics, aged under 40 and no taller than 5 ft. 11 in.

A closed-loop control system which consists of an attitude sensor with reaction controls will be used. The reaction controls will keep the vehicle in a specified orbital attitude and will establish the proper angle for retro-firing, re-entry, or an emergency manœuvre.

Either manual or automatic control can be used by the pilot during orbital flight. During manual control, optical displays will permit him to see portions of the Earth and sky so that he can place the capsule in the desired orbital attitude.

The re-entry system will supply sufficient impulse for atmospheric entry in less than one-half an orbital revolution after firing of the retro-rockets. These rockets will be fired by a signal either from ground control or by the pilot himself. The impact area can be predetermined because the capsule's point of re-entry into the atmosphere can be controlled.

As the capsule re-enters the Earth's atmosphere and slows to about Mach 1, a drogue parachute will open to stabilize the vehicle. At this time, radar "window" will be released so that the capsule's location can be pinpointed. When the velocity of the capsule decreases further, a landing parachute will open at an altitude high enough to permit a safe landing on land or water. After landing, recovery aids will include tracking beacons, a high-intensity flashing light system, a two-way radio, marker bombs and dye markers.

In an emergency before orbital altitude is reached, escape systems will separate the capsule from the booster.

There will be two-way communication between the pilot and the ground stations during flight. Equipment will include a two-way voice radio, a receiver for commands from the ground, telemetry equipment for transmission of data from the capsule to ground stations, and a radio tracking beacon.

Supersonic Research at Bedford

AMONG the comprehensive programme of work planned for the Aircraft Research Association's wind-tunnels at Bedford, are tests on the industry's supersonic airliner projects discussed in THE AEROPLANE for January 9, 1959. At present this work is confined to a preliminary study of the various configurations with a view to determining the most economic shape—and comes within the province of the Association's large 8 ft. by 9 ft. transonic tunnel. In due course, however, the new supersonic tunnel at Bedford—described in detail in THE AEROPLANE of January 23—will be used for part of this research.

During a Press demonstration of this important addition to the industry's co-operative research facilities recently the chief executive of the A.R.A. expressed himself as well satisfied with the new tunnel. The Association, he said, felt that it had now got one of the best pieces of equipment in its class in the World. With a working section measuring 2¼ ft. by 2¼ ft. the new tunnel covers a Mach number range of 1.4 to 3.5.

Although it has only recently been completed, it has already been used for two urgent problems requiring solution for member companies. One concerned a guided missile and the other a supersonic engine air intake. At present it is being used for an exploratory set of tests with a standard AGARD delta-wing model which is being tested in a number of supersonic tunnels so that their characteristics can be directly compared.

Future work for the supersonic tunnel will be associated primarily with guided missiles and engine air intakes in the supersonic field. Also it is planned to investigate the effects of jet efflux flow on the characteristics of body shapes. These last-named tests will be done "cold" with compressed air ducted to the model to simulate the jet exhaust.

At the present time, the A.R.A.'s transonic tunnel is engaged on some turboprop intake investigations for Rolls-Royce exploring the effect of blade root shape and intake duct profile on the flow into the Tyne. This tunnel will be used, too, for studying the aerodynamics of engine silencers for the supersonic transport in order to find the best compromise for an effective low-drag unit.

To date 18 models have been tested in this tunnel. These have comprised six military aircraft, two missiles, seven civil transport aircraft, and three research aircraft.

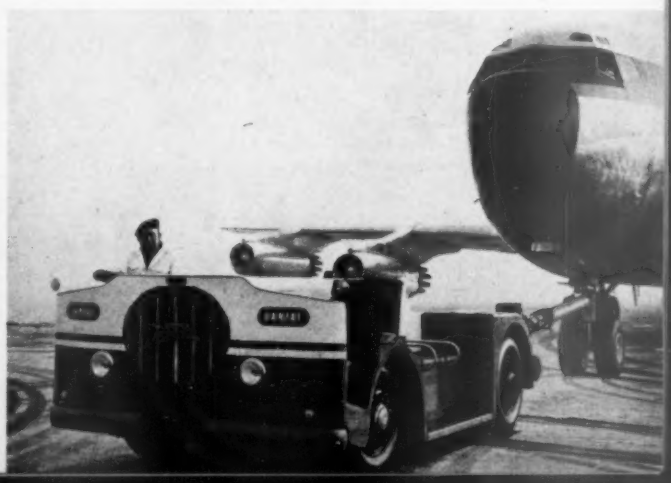
A new partner in the Aircraft Research Association—which now has 15 member companies—is the Aircraft Manufacturing Company formed by de Havilland, Hunting Aircraft and Fairey to produce the new D.H.121 jet airliner for B.E.A. And it was interesting to see in the model shop, during our visit, the wing of the D.H.121 model being made; a model of the Blackburn and General Aircraft NA.39 was also nearing completion.

F. N. Hillier

FRANK HILLIER, whose death we reported briefly last week, was born on February 2, 1894. After education at Dulwich College, he was commissioned in the R.F.A. in the First World War, and was in the Special Reserve from 1915 to 1919. He served the *Daily Mail* and *The Times* as special correspondent in France and the U.S.A. between 1919 and 1922, and among his commissions was the coverage of the first Atlantic flight attempts.

He was managing editor of the *Westminster Gazette* until it was merged with the *Daily News*, of which his father, F. J. Hillier, was a director, and continued on that paper. He also worked on the *News Chronicle*, and was foreign editor of the *Daily Mail* from 1935 to 1938. That year he joined the Ministry of Home Security as press and publicity officer. Three years later he went to B.O.A.C. as publicity controller and then held a similar post with B.S.A.A. until it was merged with B.O.A.C.

He had many friends in Fleet Street and in aviation generally. To his widow and son, our sympathy is tendered.



TRACTIVE EFFORT.—At London Airport last week this Douglas Tugmaster D.C.7Q airport tractor demonstrated its ability to move aircraft such as the Boeing 707 with ease and at speed. Powered by a 230-h.p. Leyland diesel, it has been specially developed to handle the new generation of long-range transports.

Photograph copyright "The Aeroplane"

3kVA invertor

in service on the Vickers Vanguard

This compact new 3 kVA Invertor by Plessey — already ordered to serve aboard the Vanguard — is designed to convert general d.c. supply to three-phase alternating current for aircraft instruments and allied equipment. It has an excellent power/weight ratio, features close frequency control and is self-cooled. The control box is mounted integrally with the Invertor and houses the starting gear, radio suppression components and the voltage regulator. Design Engineers who are interested in this or other Plessey aircraft equipment are invited to request full technical information.

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Alloy	Stress T sq in	Temp	Hours to Rupture Minimum
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NIMONIC 100	7	940°C	30
NIMONIC 105	7	940°C	**50**

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Correspondence

Whittle and the Two-tier Fan

PUNCTUALITY is an acknowledged virtue, but your article Enter the "Fan-jet" (January 2, 1959) suggests that oblivion may await the inventor with the initiative to be "before his time." Some no doubt remember that Sir Frank Whittle invented the "by-pass" engine and that the maximum possible extension of the life of the relevant patent was obtained in 1952, the Court deciding that external circumstances had delayed development of an outstandingly meritorious invention.

A high degree of engineering skill has no doubt gone into the design of the General Electric CJ-805-21, with its free-running turbine having outer fan-forming sections to its blades, but let us not forget that Britain's Sir Frank also invented and patented the two-tier ducted fan. Unlike the by-pass concept, that of the two-tier fan did receive some early practical attention in this country; examples were made and tested in the early '40s, in conjunction with various single spool-engines, built by Metropolitan Vickers and Power Jets.

T. G. HICKS.
London, W.1. (Managing Director, Power Jets (Research and Development), Ltd.)

The Excellence of the Avro Baby

WREN'S interesting article (on January 23) on Gustavus Green is very good reading. It may help to emphasize just how good Mr. Green's products were if I quote from a full-page Avro advertisement in your issue of September 7, 1921. It is headed:—

THE AVRO BABY
Type 538 Engine 35-40 h.p. Green
The most successful and economical
small aeroplane in the world.

The petrol consumption is remarkably low. Several long flights have been accomplished showing a petrol consumption of *35 miles to the gallon.*

RELIABILITY. Details of some of the meritorious flights performed by the Avro Baby during the past two years are given below. London-Brussels non-stop, August, 1919, 2¼ hrs. Aerial Derby Handicap, 1919, Winner. Aerial Derby Handicap, 1920, 1st and 2nd. London-Turin non-stop, 9¼ hrs. Sydney-Bundaberg non-stop (about 800 miles), 9 hrs., April, 1921.

Price: £750 Single-seater. Price: £800 Two-seater.

Now all this was some four years before the D.H. Moth appeared to usher in the new era of long distance light aeroplane records and is a remarkable tribute to the reliability of the four-cylinder Green and of the small aeroplane it drove.

The Avro Baby was just a bit too far ahead of its time to catch the popular fancy in the way that the Moth did and the fact that the Baby was basically a single-seater would have made it less saleable, no doubt.

Ipswich. H. J. PARHAM.

IATA and Lower Fares

RECENT events in the field of air transportation have highlighted the fares monopoly and the fact that IATA have yet to agree fully over the different fare structures.

At present, our air corporations, in particular B.E.A., although anxious to reduce fares to attract a larger share of traffic, have to take a stand in which they oppose the operations of the independent companies who, being under less control, can offer fares at prices which would, in effect, be similar to those which the corporations would like to offer. The proviso that such operations will not affect those of the corporations is somewhat foolish in that it is obvious to all that people will travel by the cheapest method, and will even put off their journey until they can get a seat on the cheaper route.

The resultant troubles are causing very bad publicity and friction, and one only hopes that IATA will soon come to an agreement before they "throttle" to death quite a few of their members.

Gibraltar. P. L. BURNET.

Fourteen MACships

I WAS most interested in the letter about MACships from Wm. Thomson and Co. in your issue of January 9 last. I had not appreciated before that some MACships had hangars to accommodate their aircraft and were specially built for the job.

Since I originally wrote to you on this subject, I have unearthed what I believe is a complete list of MACships. There appears to have been a total of 14, but perhaps somebody can confirm this.

The MACships were named: Empire MacAlpine, Empire MacKendrick, Empire MacAndrew, Empire MacCabe, Empire MacCallum, Empire MacColl, Empire MacDermott, Empire MacKay, Empire MacMahon, MacOma, Miralda, Adula, Gadila, Alexia.

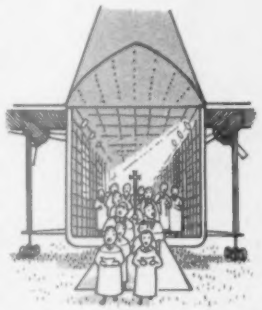
Ruislip, Middx. PETER W. BROOKS.

Groundabout

Aero-nautical. "A leading British naval architect was recently seen . . . carrying a copy of that renowned publication *The Aeroplane.*" So says "Tritonian" in that renowned publication *Lloyd's List* and very decently gives the commendable reason for this apparent treachery. Put simply, the I.B.n.a. knows he can learn from aerodynamics and, in fact, has already profited thereby, having based a ship's propeller design on aeronautical research results and got a 20% more efficient article. As "Tritonian" sums it up, "Repugnant though the thought is, it does seem that grandmother can learn something from her still-wet-behind-the-ears grandchild!"

*

Nave-l Architecture. I wonder why aviation didn't follow naval precept and use the name "architect" instead of "designer"? After all, right at the beginning there was the Cathedral of Cody and even today there's the Beverley edifice with its Minster-like architecture planned by Freddie Crocombe when he was General Aircraft's Aeronautical Architect. It was subsequently erected at the Brough Yards.



*

Biting the Hand. The curse of good intentions misunderstood has put its troublesome finger on the Automobile Association. This fine organization, being on the ball, owns a Rapide and uses it to help its members. When the Caithness area was heavily snowbound recently, the Rapide reconnoitred local road conditions and dropped emergency food packs to an A.A. patrolman to give to stranded motorists if necessary. A simple, thoughtful act, you think? Not a bit. It soon became "A.A. HELICOPTER DROPS SUPPLIES TO MAROONED VILLAGE," to the indignation of the 34 citizens of Braemore, who can look after themselves, and the annoyance of the Caithness Public Health Committee, who can look after Braemore. Implied incapability, hurt pride, Highland-wide complications, demands for more snow-ploughs—oh, brother!

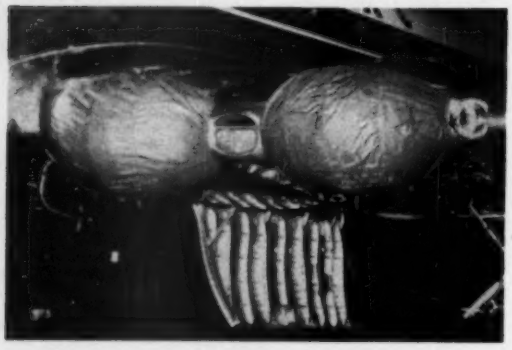
*

Dept. of Suspended Revelation

Few things are more irritating than having to wait until next week to be given the answer to a puzzle in this week's issue, but when I came across the picture below, which I took last year, I thought it might intrigue you—answer next week.

by Gren

NOTES AND EVENTS



COMET COVERS.—Lightweight engine-intake covers made from Hydex proofed nylon fabric manufactured by British Nylon Spinners, Ltd., are used by B.O.A.C. on their Comet 4s. The covers are extremely strong and durable and have a high tear strength.

COMPANY MOVE.—Cossor Radar and Electronics, Ltd., one of the Cossor group of companies, has moved from Aberdeen Works, Highbury, London, and is now operating from new premises at Harlow, Essex. The only major unit of the company now outside Harlow is the service department, which remains at West Norwood, and there is a London office at Cossor House, Highbury Grove, N.5.

INSTRUMENT SHOW.—The fifth International Instrument Show, sponsored by B and K Laboratories, Ltd., will be held at the International Instrumentation Centre, 4 Tilney Street, Park Lane, London, W.1, from April 6 to 10. Applications for tickets should be made to the organizers at 4 Tilney Street (Grosvenor 4567).

GERMAN APPROVAL.—After four years of technical negotiations and tests, six of the principal models of Nu-Swift pressure-charge-operated fire extinguishers have been approved by the West German Government.

AIR LEAGUE HISTORY.—It is proposed to publish early in April an official history of the Air League to commemorate its Golden Jubilee. Anyone with material, such as anecdotes or photographs, which might be included is invited to get in touch with Mr. Gavin Cochrane, c/o the secretary-general, Air League of the British Empire, 19 Park Lane, London, W.1.

ENGINE FAILURE.—A study to determine a reliable method for predicting jet-engine failures and malfunctions is being conducted at the U.S.A.F. Strategic Air Command's Lockbourne A.F.B. by a research team from Battelle Memorial Institute, Columbus, Ohio. The study is sponsored by the Flight Control Laboratory, Wright Air Development Center. Final aim of the study is to develop a simple totalizing recorder-computer that could be installed on jet engines to predict expected service life or the need for maintenance.

CHANGE OF ADDRESS.—Technivision, Ltd., have moved their studio and offices from Station Chambers, 115 King Street, Maidenhead, Berks, to Braywick House, Maidenhead. The London office at 51 Brompton Road, S.W.3, is retained.

ICE DETECTION.—Canadian Applied Research, Ltd., of Toronto, has introduced a new portable ice-detector test set—type T272 Mk. 2—for checking its range of ice detectors. It can be used for testing the ice-detection system installed in an aircraft or on the bench.

IN BELGIUM.—Twenty-two industrial groups, one of which includes aircraft and aero-engines, form the 11th Liège International Fair to be held from April 25 to May 10. Applications for exhibition space (closing date, February 28), can be made through the Fair's United Kingdom representative, Mr. R. C. Liebman, 178 Fleet Street, London, E.C.4.

SERVO LEAFLET.—Details of newly developed DC transistorized servo units are given in a leaflet published by Servo Units, Ltd., of Farnborough, Hants. These units give a high stalled torque and can be used from 6- or 12-V. DC or from AC mains via a transformer and rectifier unit.

FIBRE ORDER.—Japan has now become the latest country to order glass-fibre material from Glass Yarns and Deeside Fabrics, Ltd., of Camberley.

NEW TENANTS.—The Ministry of Supply factory at Brockworth, Gloucester, has been bought by British Nylon Spinners, Ltd., who will move in when the present tenants, Armstrong Siddeley (Brockworth), Ltd., cease production.

SATELLITE SYSTEMS.—Collins Radio Co., of Cedar Rapids, Iowa, U.S.A., will provide the electronic instrumentation of the manned satellite capsule to be built by the McDonnell Aircraft Corpn. for Project Mercury. The equipment will include radio voice communications, telemetry, guidance, tracking and rescue radio-beacon systems.

RUSSIAN RESEARCH.—The Department of Scientific and Industrial Research's lending library unit has introduced a new publication, "The L.L.U. Translations Bulletin." This aims to provide up-to-date information on the availability of Russian translations dealing with current U.S.S.R. research. Published monthly by H.M.S.O., price 4s. (postage 5d.), it lists books, journals and other scientific papers which are now available or which are being translated and will be obtainable in the near future.

OFFICE TRANSFER.—Microcell, Ltd., has transferred its sales, purchasing, contracts, design, accounts and publicity departments from Imperial Buildings, 56 Kingsway, to Ingersoll House, 9 Kingsway, London, W.C.2. The new telephone number is Covent Garden 1262.

Aviation Calendar

February 7.—British Interplanetary Society lecture, "High Energy Fuels and Rocket Propulsion," by Dr. F. Fitzgerald (Birmingham College of Technology), at Caxton Hall, Caxton Street, **London,** S.W.1, at 18.00 hrs.

February 9.—R.Ae.S. Halton Branch lecture, "Flying the F.D.2," by L. P. Twiss (Fairey Aviation), at the Branch H.Q., R.A.F., **Halton,** at 18.45 hrs.

February 9.—R.Ae.S. Cambridge Branch, film show, in No. 1 lecture theatre, University Engineering Laboratories, **Cambridge,** at 20.15 hrs.

February 11.—Society of Instrument Technology, Data Processing Section lecture, "A Digital Instrumentation System for Use in the Testing of Jet Engines," by L. Airey, at Manson House, Portland Place, **London,** W.1, at 18.00 hrs.

February 11.—R.Ae.S. Chester Branch lecture, "The History and Development of Manchester's Airports," by G. A. Harvey, in the lecture theatre, Grosvenor Museum, **Chester,** at 19.30 hrs.

February 11.—R.Ae.S. Manchester Branch lecture, "Flight Corridor Research," by J. E. Allen (A. V. Roe), in the Reynolds Hall, College of Technology, **Manchester,** at 19.30 hrs.

February 11.—R.Ae.S. Reading Branch lecture, "Noise," by Prof. E. J. Richards, in the Western Manufacturing, Ltd., canteen, **Reading,** at 18.15 hrs.

February 11.—Kronfeld Club, talk by Chris Riddell on Tipsy aircraft, at 74 Eccleston Square, **London,** S.W.1.

February 12.—R.Ae.S. Main Lecture, "Earth Satellites," by W. H. Stephens, at the Institution of Mechanical Engineers, Birdcage Walk, **London,** S.W.1, at 18.00 hrs.

February 13.—R.Ae.S. Presidential Reception, at 4 Hamilton Place, **London,** W.1, at 19.30 hrs.

February 13.—Plymouth Aero Club, annual dinner and dance, at the Duke of Cornwall Hotel, **Plymouth.**

February 16.—R.Ae.S. Henlow Branch, student members' papers, in Building 62, R.A.F. Technical College, **Henlow,** at 19.30 hrs.

February 17.—R.Ae.S. lecture, "Engine Starting Systems," by R. H. Woodall, in the library, 4 Hamilton Place, **London,** W.1, at 19.00 hrs.

February 18.—Aircraft Recognition Society, talk by Peter G. Masefield (president), in the R.Ae.S. Library, 4 Hamilton Place, **London,** W.1, at 19.00 hrs.

Birth Notices

Fraser.—On January 20, at Cressbank Hill, Hurworth-on-Tees, Darlington, to Angela (*née* Shaw), wife of Flt. Lt. A. W. Fraser—a daughter.

Harvey.—On January 20, at the Rutland Memorial Hospital, Oakham, to Ann, wife of Flt. Lt. J. D. Harvey—a daughter.

Laird.—On January 20, at R.A.F. Hospital, Halton, to Alison (*née* Laing), wife of Sqn. Ldr. Stuart Laird—a son.

Lambert.—On January 19, at R.A.F. Hospital, Changi, Singapore, to Carol (*née* Plascott), wife of Flt. Lt. J. D. Lambert—a daughter.

Stevens.—On January 20, at R.A.F. Hospital, Halton, to Rosemary (*née* Walters), wife of Flt. Lt. A. R. Stevens—a daughter.

Company Notices

OVERSEAS COMPANY

Spartan Air Services, Ltd. (F.4,762).—Particulars filed Jan. 13, 1959, pursuant to Section 407 of the Companies Act, 1948. Cap., stock: 1,350 Class "A" preferred shs. of $100, 8,500 Class "B" preferred shares of $100 and 750,000 Common shs. without nominal or par value. Reg. in Canada, Aug. 30, 1946, to make aerial photographic survey maps, plans and timber cruises, etc. British Address: 12 Whitehall, London, S.W.1, Wilfred G. F. Ilott, of 16 Common Close, Horsell, Woking, authorized to accept service of process and notices. Directors: John A. Roberts, Russell L. Hall, Donald W. Hayworth, Leonard N. Watt, John S. Gairdner, John M. Coyne and William H. Morton, all resident in Canada.

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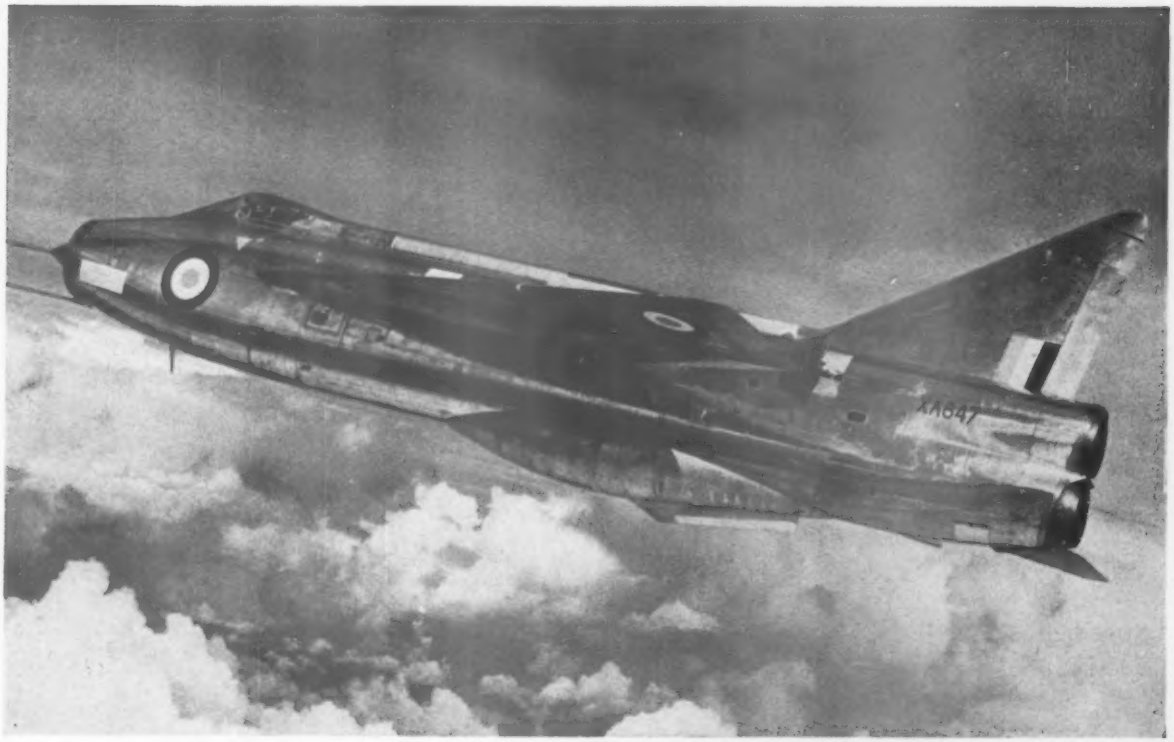

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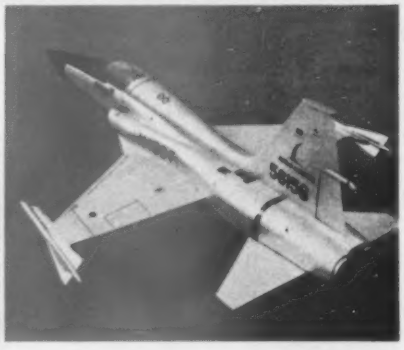

...NEWS IS HAPPENING AT NORTHROP

NEW N-156F FIGHTER COMBINES MACH 2 DEFENSE AND EASE OF MAINTENANCE WITH MINIMUM COST

The Northrop N-156F counterair fighter offers NATO and SEATO nations a highly effective weapon system at little more than half the cost of comparable fighters. Many N-156F parts are interchangeable in Northrop's T-38 trainer, which was developed in parallel and is now in production for the USAF. The fighter has been designed for manufacture in countries where it will be used. In addition, its systems and components are both simple and accessible, eliminating the need for rare skills for maintenance. The twin-jet N-156F is a unique weapon designed to meet the specific military requirements of NATO, SEATO and other free allied nations—designed to provide maximum defense capability at minimum cost; more fighting power for less money. *Final N-156F mockup is illustrated. First planes are now on the production line.*

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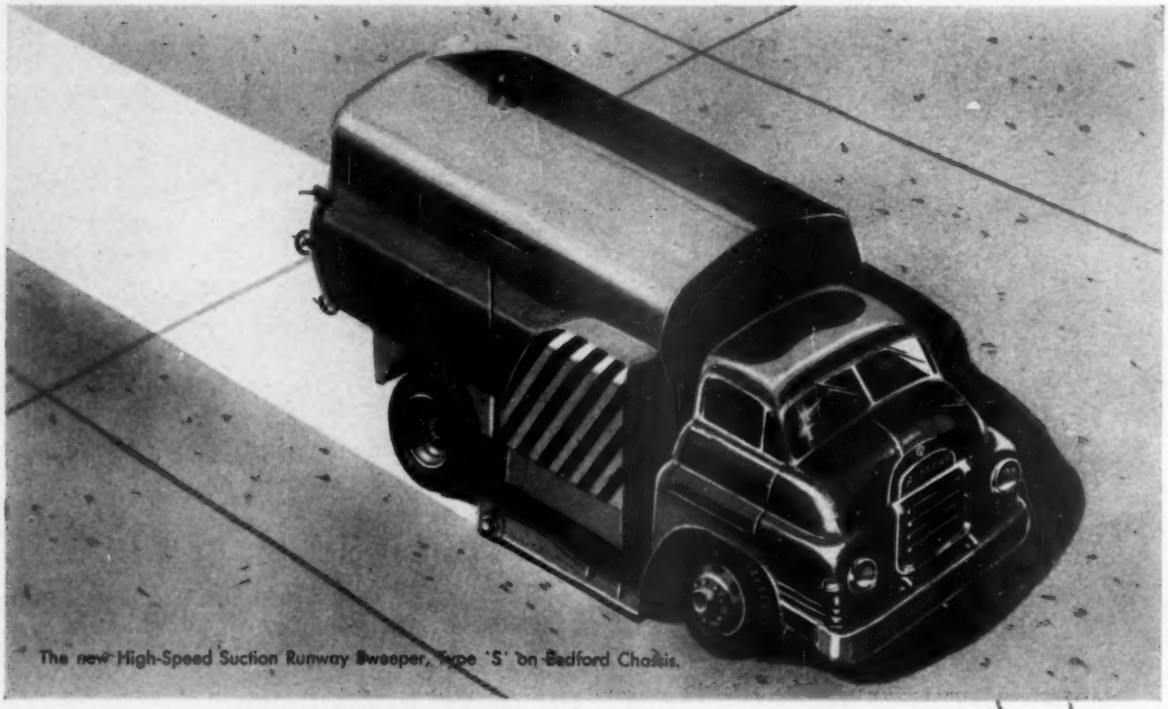

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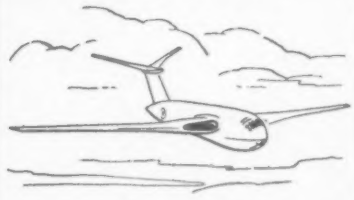
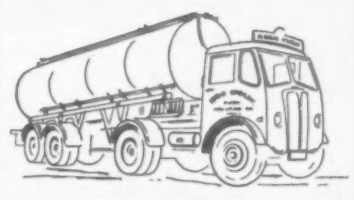
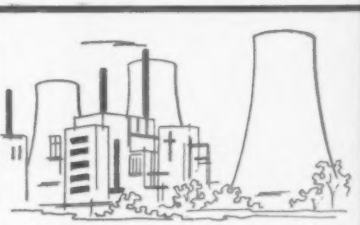


Stability and flutter on aircraft

Wind loading and control of large structures



Vehicle suspension systems



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It is an instrument of ever increasing versatility, for Shorts research engineers are continuously extending the range of non-linear computing units. Among the most recent of these is a Variable Time Switch which permits the solution of problems in which simulation is needed of transient performance under abruptly changing conditions—for example gust loading on airframes, or the effect of uneven road surfaces on vehicle suspension systems.

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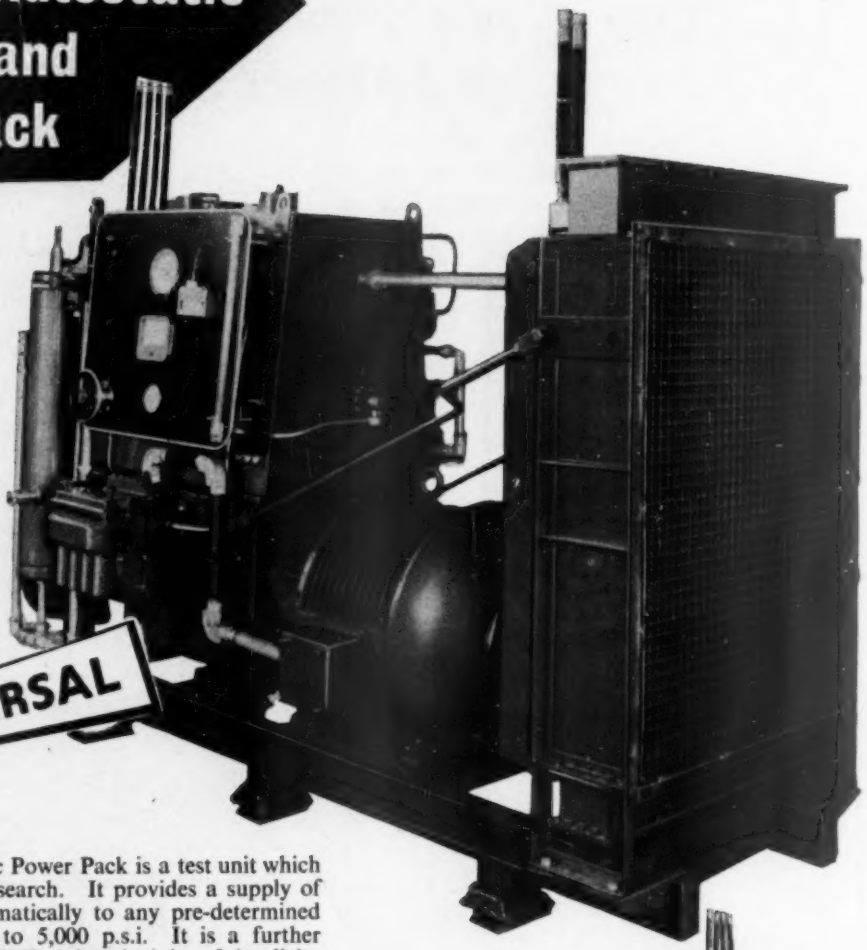
The HML Autostatic Test Rig and Power Pack



The HML Autostatic Test Rig and Power Pack, Control panel side.

IT'S UNIVERSAL

The HML Autostatic Power Pack is a test unit which is largely used for research. It provides a supply of hydraulic fluid automatically to any pre-determined pre-set pressure up to 5,000 p.s.i. It is a further embodiment of the HML twin principles of simplicity and robustness. It is specially intended for factories or laboratories where there is constant testing of hydraulic components or systems on a number of individual benches, and a virtually unlimited flow rate can be provided to suit the customer.

The HML Autostatic Power Pack is particularly well suited to the continuous power requirements of guided weapon servo-control mechanism.

Full details and specifications gladly sent on request.

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- Tensioning Test Unit
- High-speed Gear Boxes
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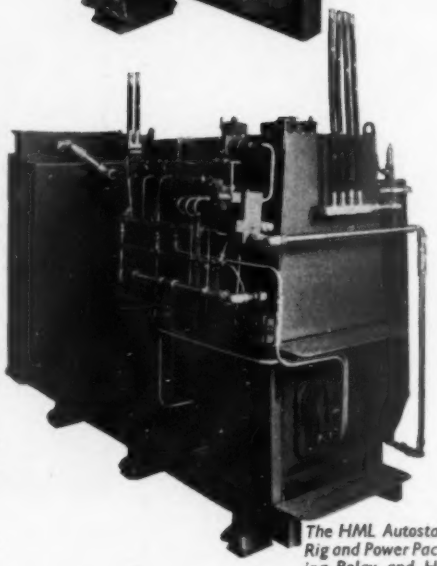
- High-pressure Accumulators
- Valves
- Universal Hydraulic Tyre Remover
- Hydraulic Propeller Test Bench



The HML Autostatic Test Rig and Power Pack, showing Relay and Hydraulic piping circuit.

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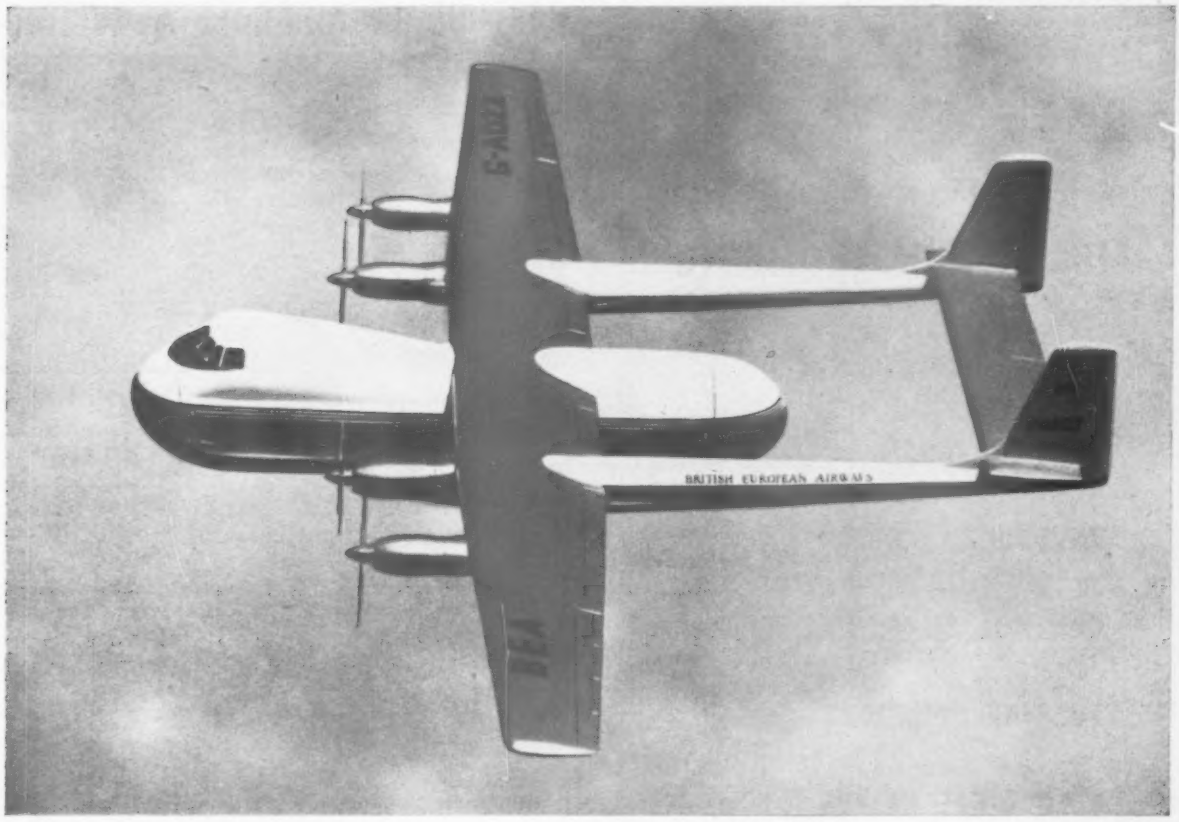

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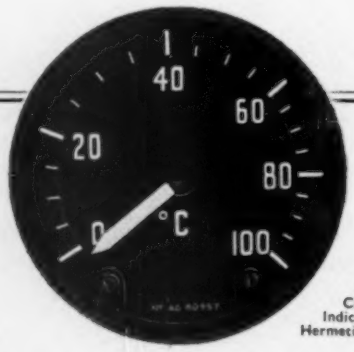

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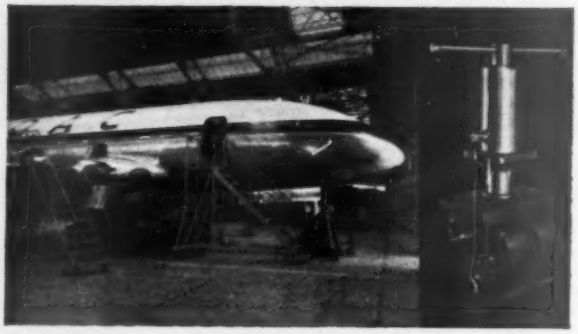

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ENGLISH ELECTRIC

AIRCRAFT DIVISION

Owing to increased development work on the P.1B Lightning supersonic aircraft, coupled with continuing design work required for Canberra variants, the long termed programme of English Electric has created vacancies for

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Jettison of canopy or drop tank, emergency release of catches or locks is achieved with these self-contained high-thrust jacks requiring no external pressure system. In both snap jacks and snap bottles, stored pressure is retained for a longer period by a metal bursting diaphragm until released either mechanically or electrically. A typical snap jack with 650 ft. lb. stored energy, 3″ stroke, initial thrust of 4,000 lb. weighs 2.4 lb.

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Anti-G valves
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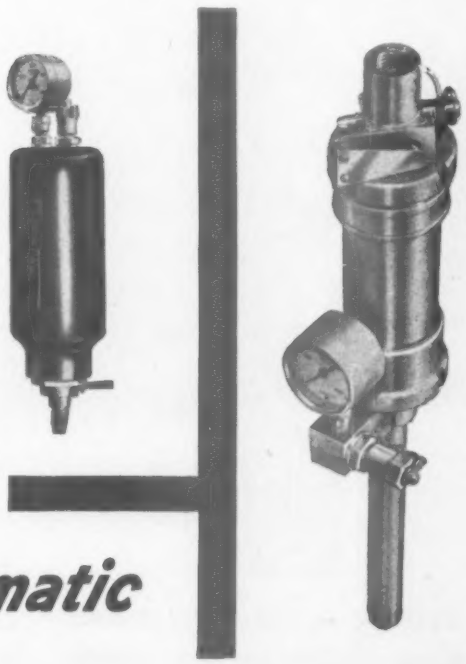

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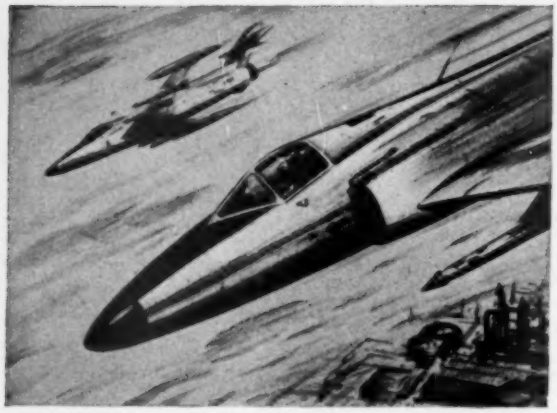

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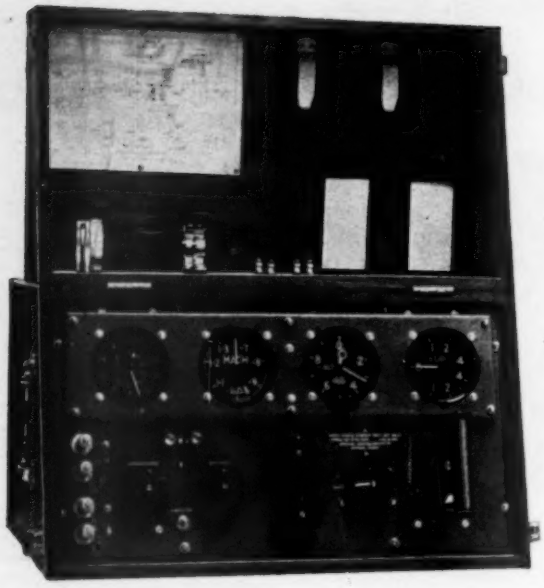

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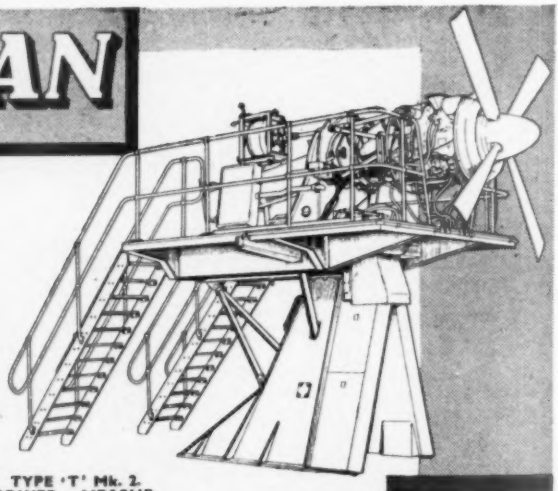

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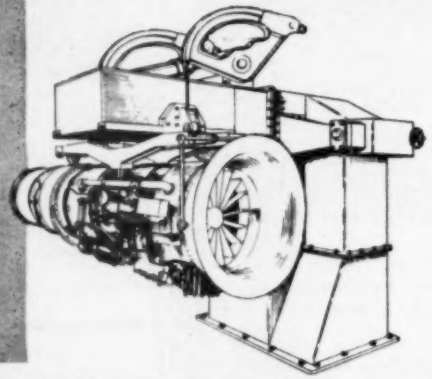

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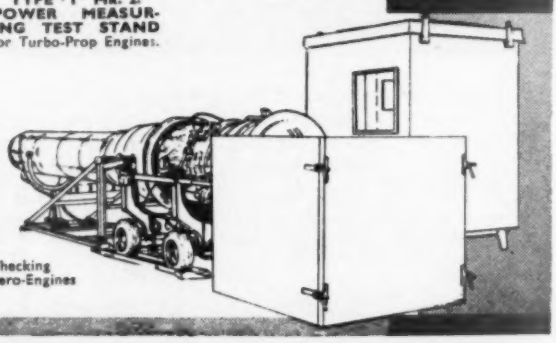

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APPLICATION NO. 2423 between Southend and Le Touquet from March 1 to October 15 each year, for the carriage of "No Passport" day-trip passengers only.

APPLICATION NO. 2424 between Southend and Ostend.

FROM B.K.S. AIR TRANSPORT, LTD., OF BERK HOUSE, BAKER STREET, LONDON, W.1:—

APPLICATION NO. 1648/1 for an amendment to the terms of approval of the Normal Scheduled Service which they are authorized to operate with Dakota and Ambassador aircraft between Leeds (Yeadon) and Basle at a frequency of two return flights weekly until May, 1965, so as to permit them to operate at an increased frequency of four return flights weekly.

APPLICATION NO. 1465/2 for an amendment to the terms of approval of the Normal Scheduled Service which they are authorized to operate with Dakota, Viking and Ambassador aircraft on the route Newcastle-Southend (tech.)-Basle at a frequency of two return flights weekly until March 31, 1965, so as to permit them to operate at an increased frequency of four return flights weekly.

These applications will be considered by the Council under the Terms of Reference issued to them by the Minister of Civil Aviation on July 30, 1952. Any representations or objections with regard to these applications must be made in writing stating the reasons and must reach the Council within 14 days of the date of this advertisement, addressed to the Secretary, Air Transport Advisory Council, 3 Dean's Yard, London, S.W.1, from whom further details of the applications may be obtained. When an objection is made to an application by another air transport company on the grounds that they are applying to operate the route or part of route in question, their application, if not already submitted to the Council, should reach them within the period allowed for the making of representations or objections. 475-1

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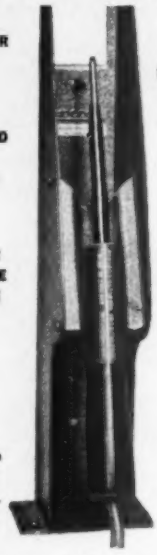

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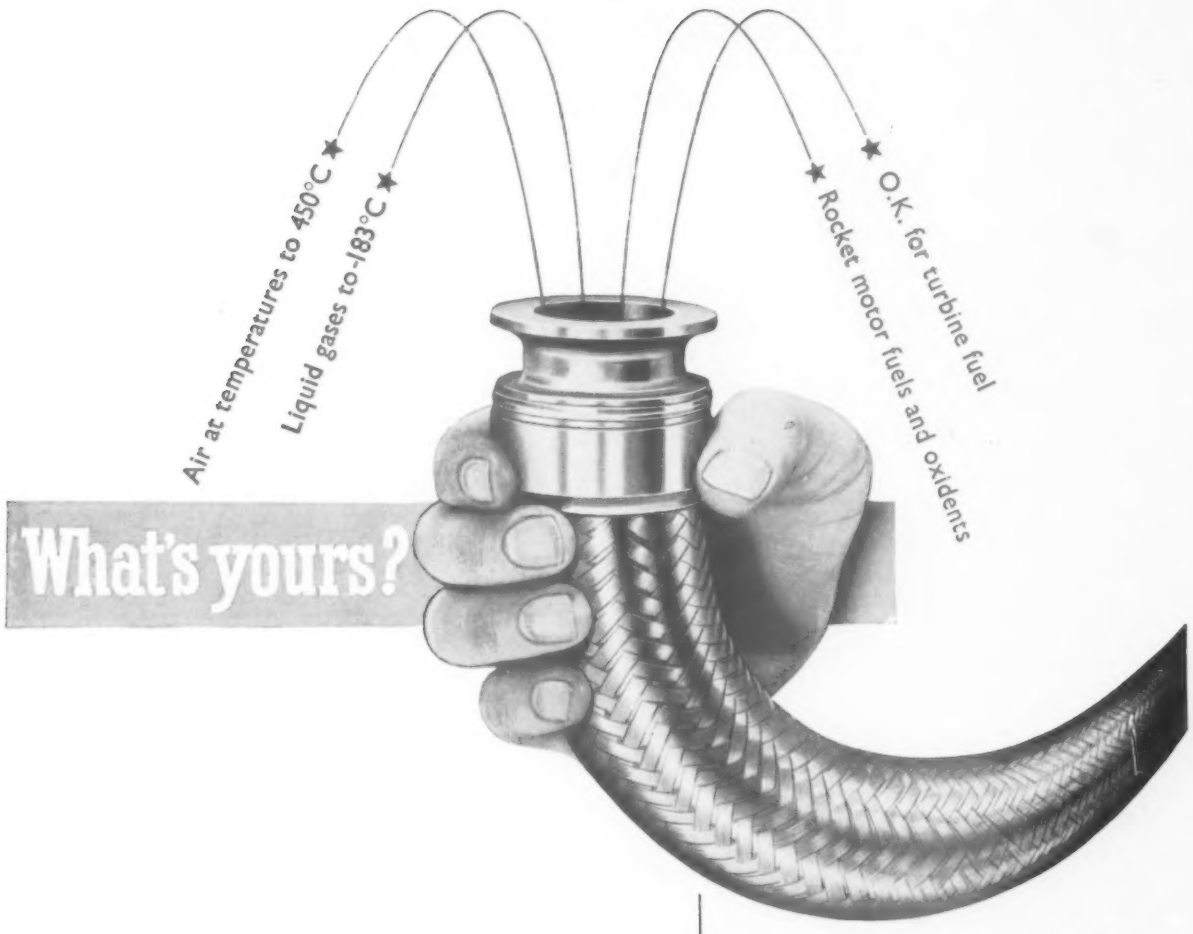

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